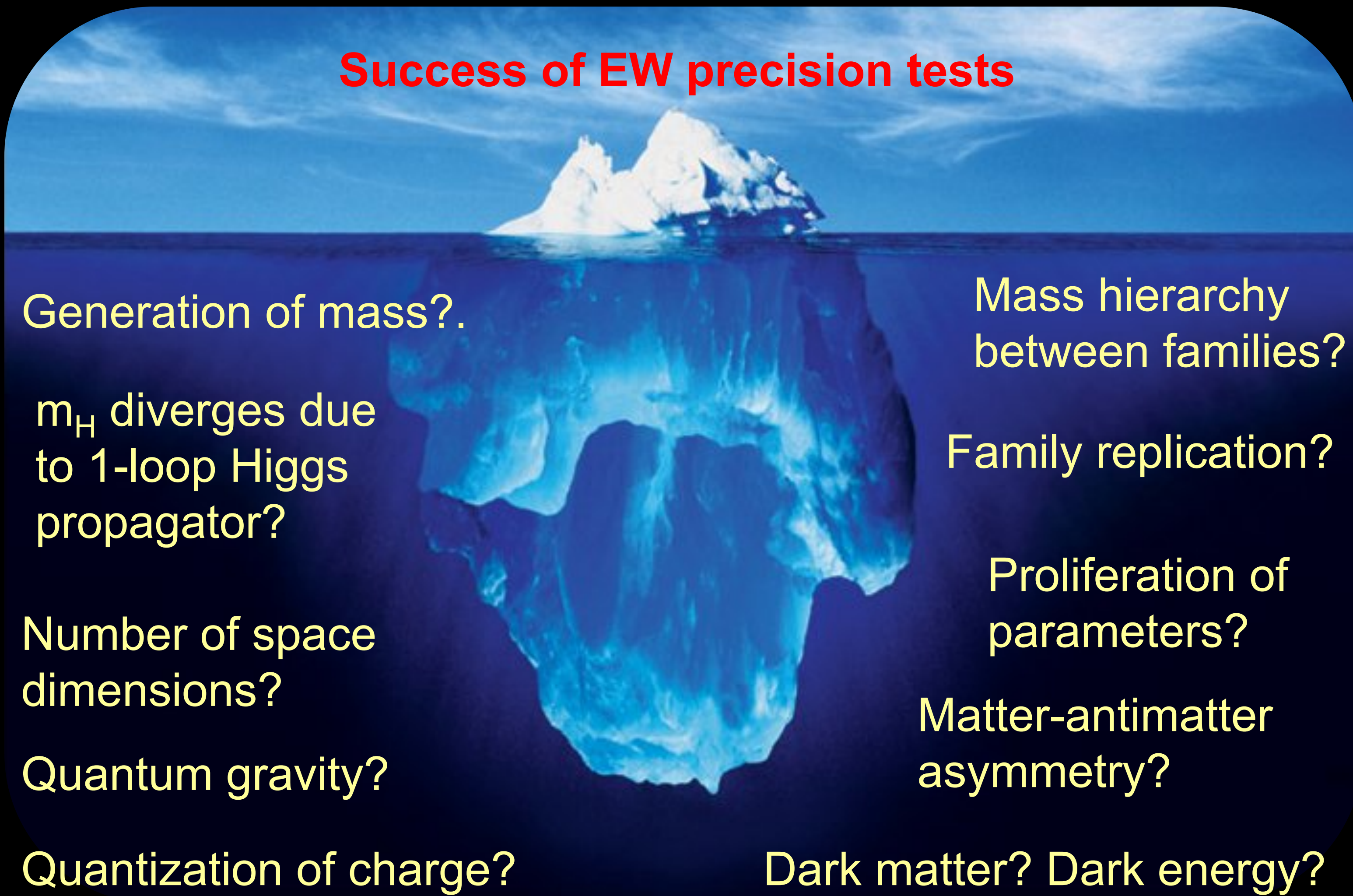
Experimental Highlights

Brookhaven Forum
2010
May 26, 2010

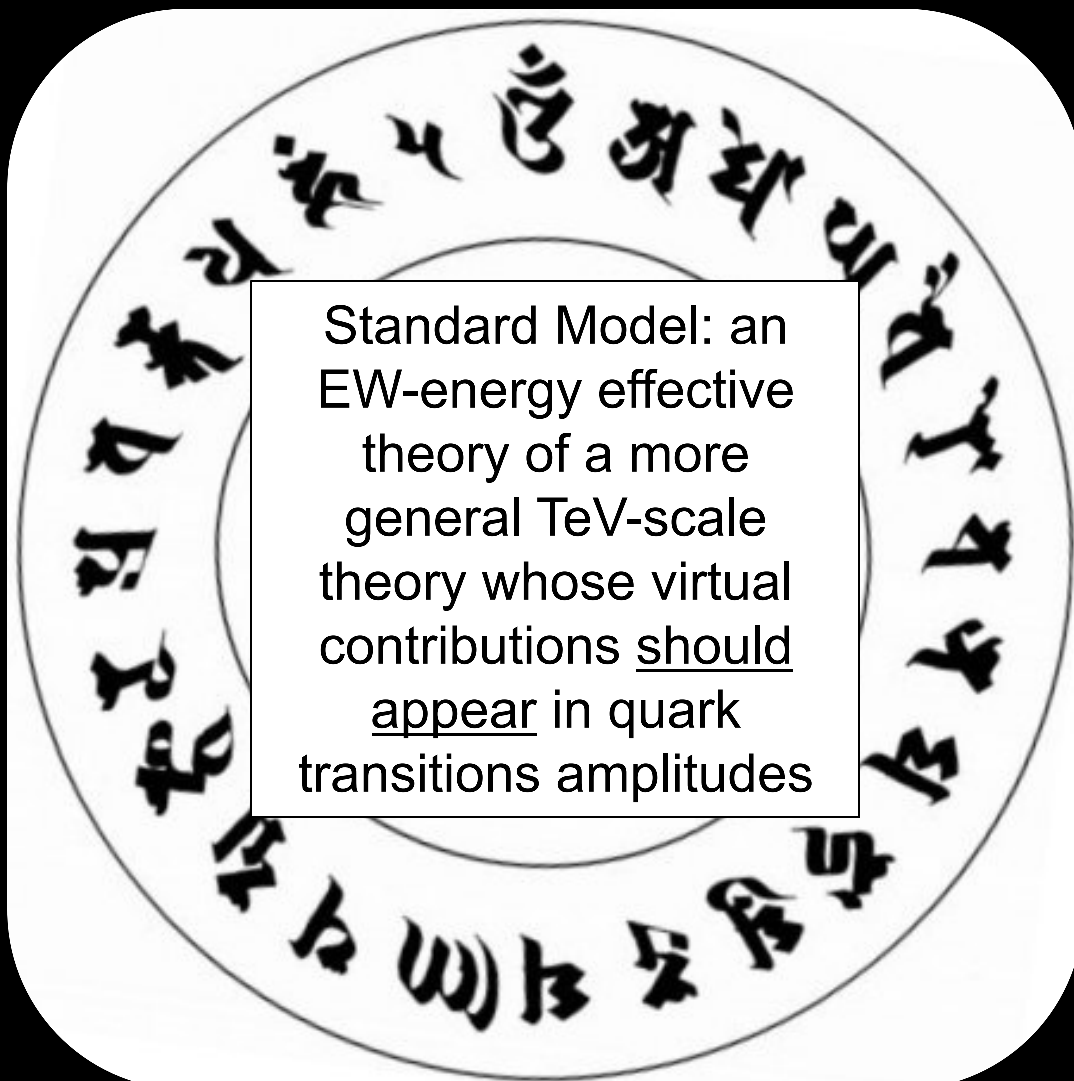
Diego Tonelli

Fermilab

After LEP


Success of EW precision tests
Generation of mass?.
m_H diverges due to 1-loop Higgs propagator?
Number of space dimensions?
Quantum gravity?
Quantization of charge?
Mass hierarchy between families?
Family replication?
Proliferation of parameters?
Matter-antimatter asymmetry?
Dark matter? Dark energy?

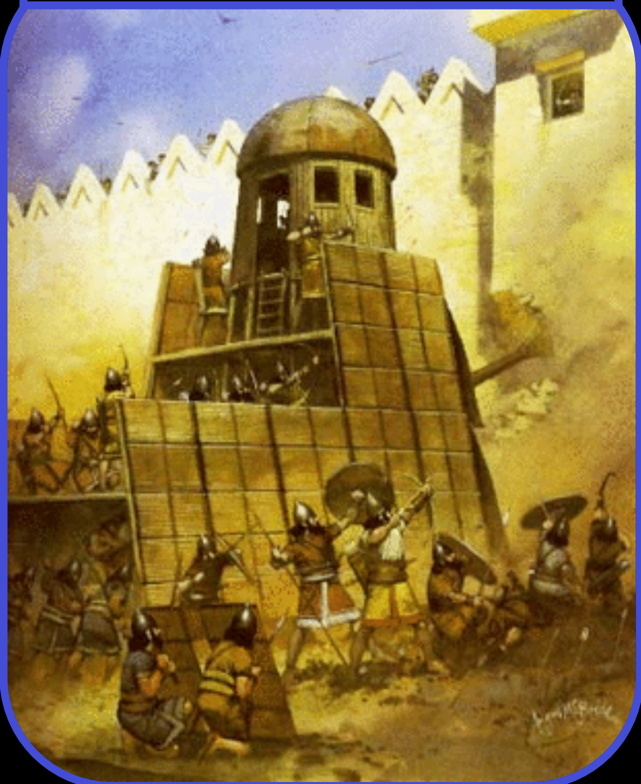
The mantra



Standard Model: an EW-energy effective theory of a more general TeV-scale theory whose virtual contributions <u>should appear</u> in quark transitions amplitudes

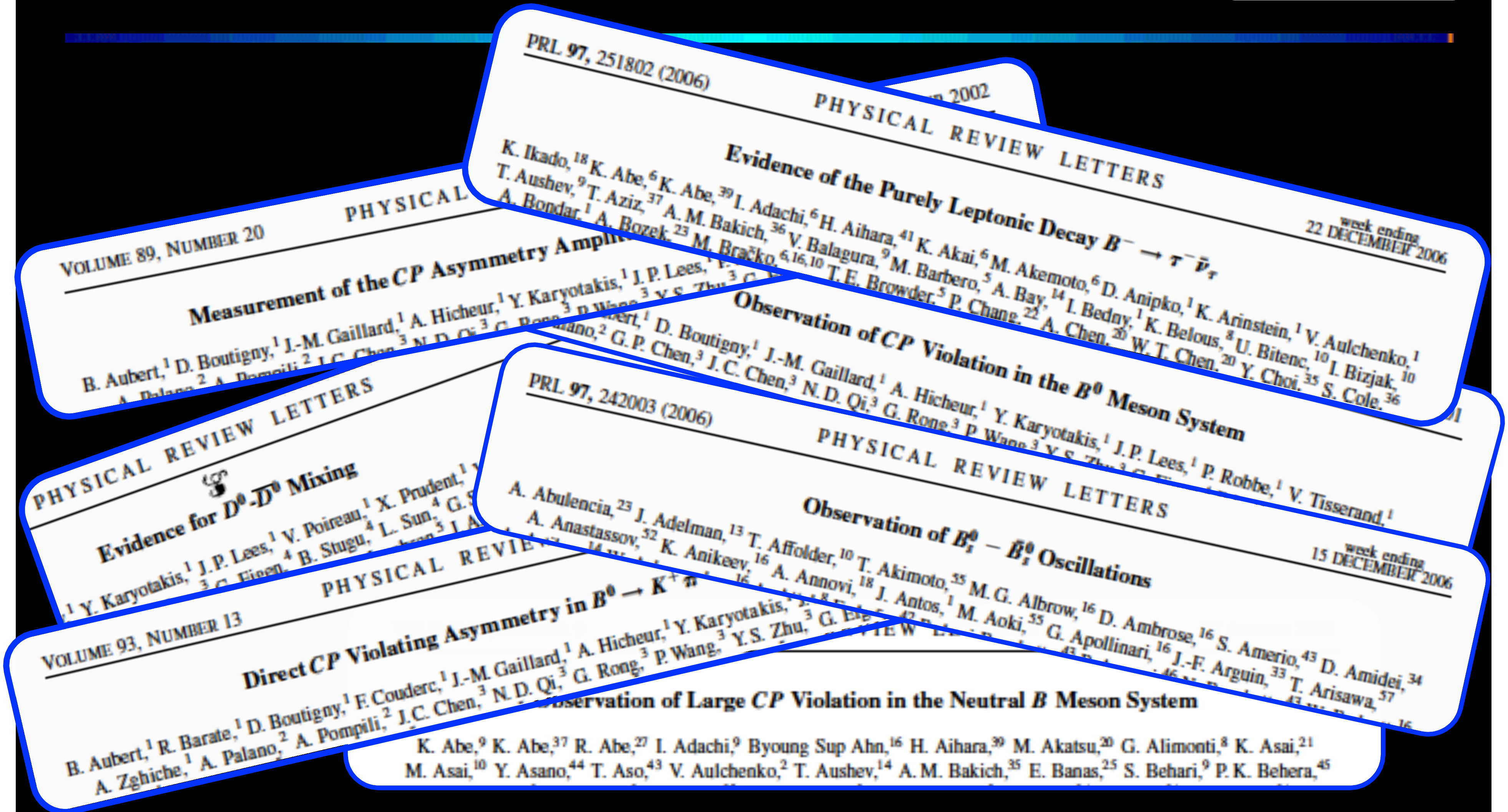
An old story

Direct (relativistic) way

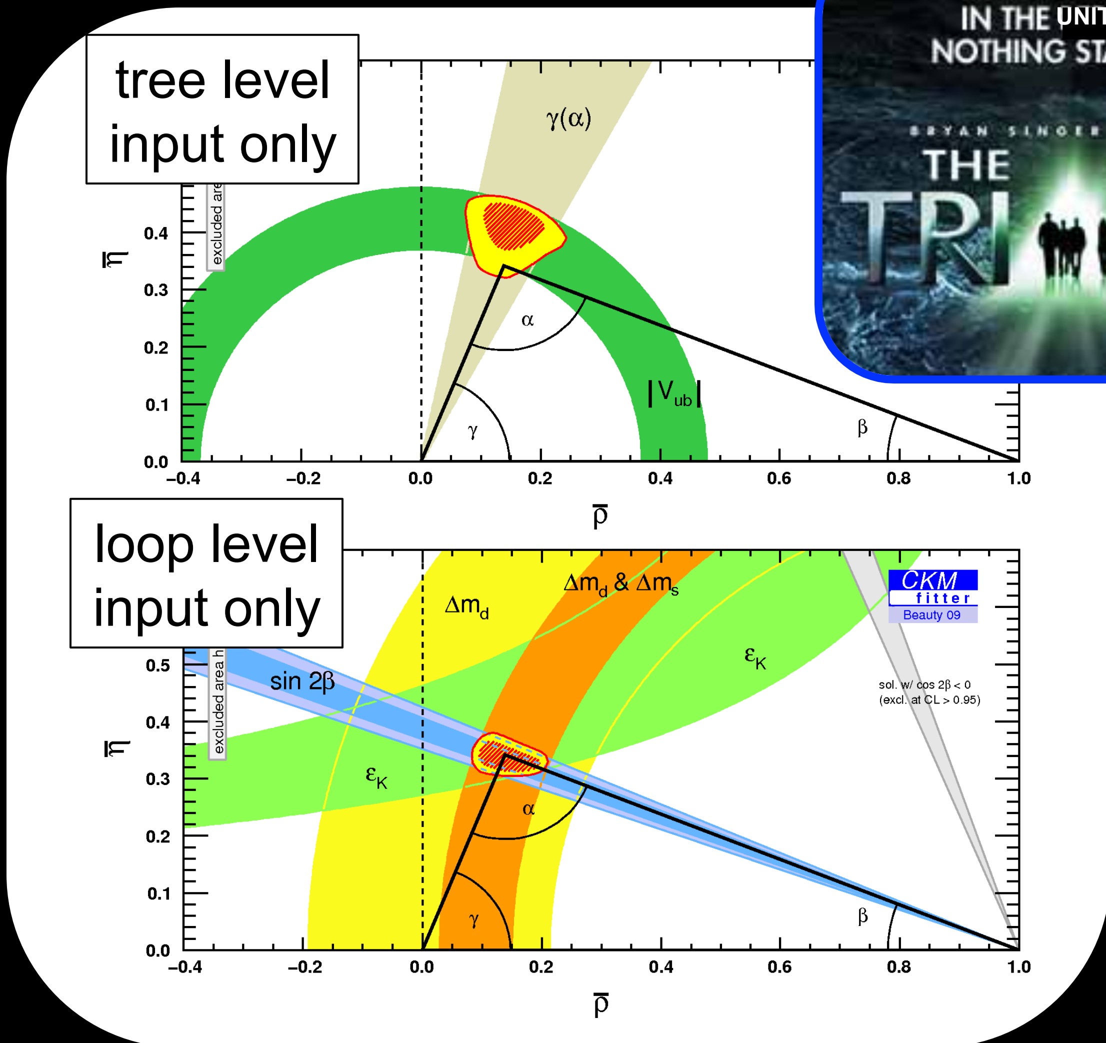


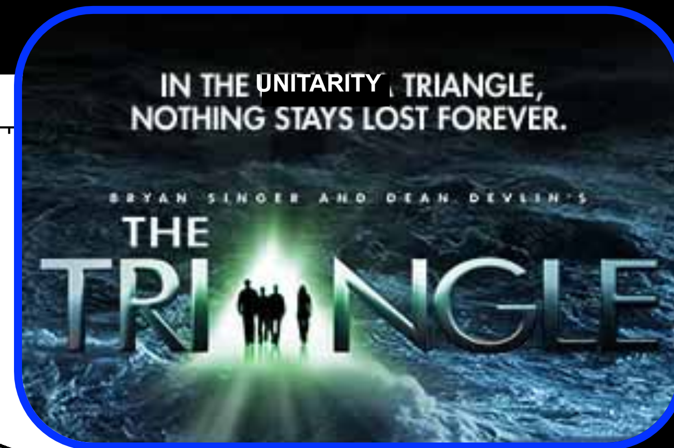
Indirect (quantum) way

Success!

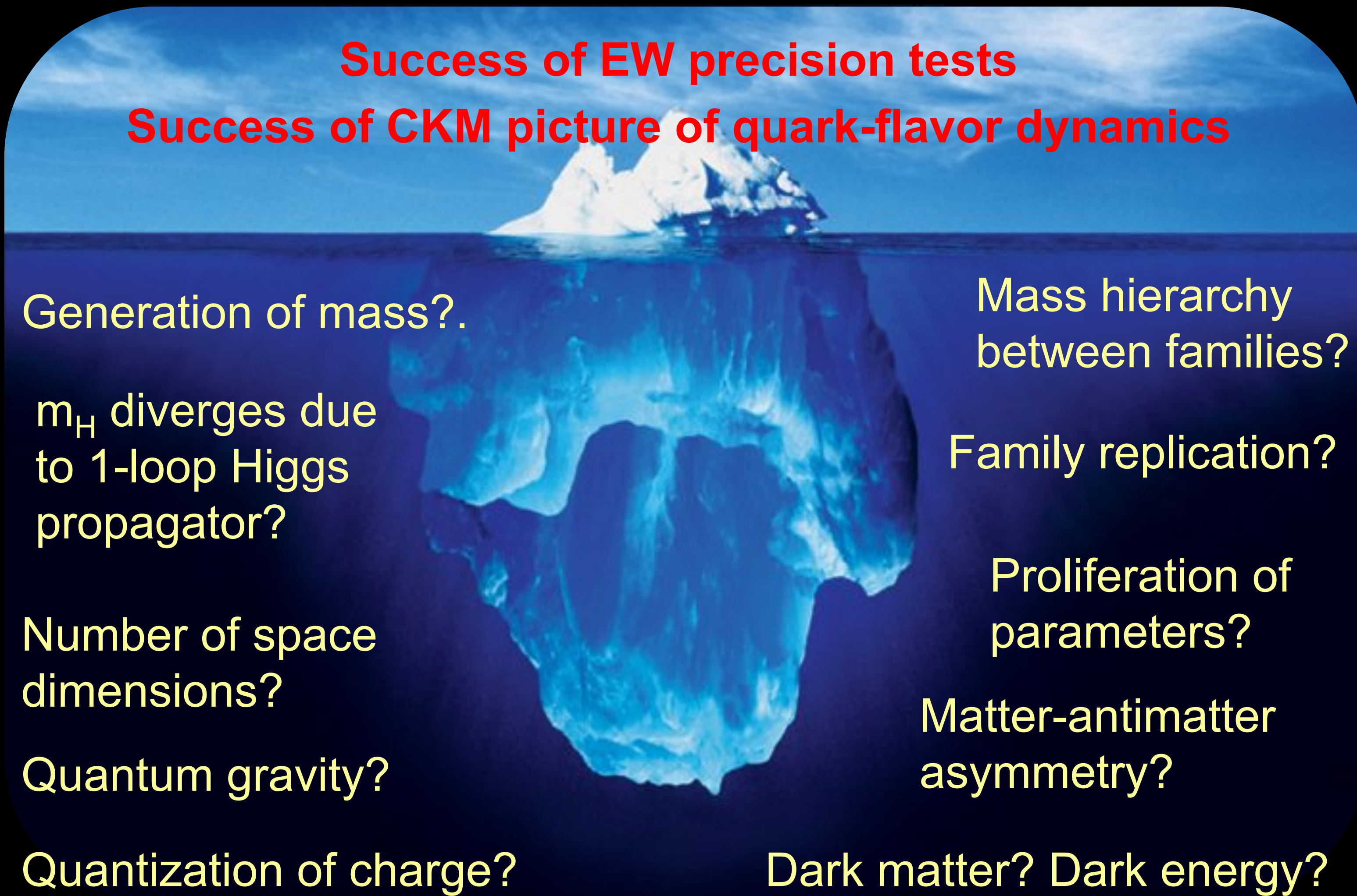

PRL 97, 251802 (2006)
PHYSICAL REVIEW LETTERS
week ending 22 DECEMBER 2006
Evidence of the Purely Leptonic Decay $B^- \to \tau^- \bar{\nu}_\tau$
VOLUME 89, NUMBER 20
PHYSICAL REVIEW LETTERS
Measurement of the CP Asymmetry Amplitude
Observation of CP Violation in the B^0 Meson System
PHYSICAL REVIEW LETTERS
Evidence for D^0-$\bar{D}^0$ Mixing
PRL 97, 242003 (2006)
PHYSICAL REVIEW LETTERS
week ending 15 DECEMBER 2006
Observation of $B_s^0 - \bar{B}_s^0$ Oscillations
VOLUME 93, NUMBER 13
PHYSICAL REVIEW LETTERS
Direct CP Violating Asymmetry in $B^0 \to K^+\pi^-$
Observation of Large CP Violation in the Neutral B Meson System

Consistency





Now


Success of EW precision tests
Success of CKM picture of quark-flavor dynamics
Generation of mass?.
m_H diverges due to 1-loop Higgs propagator?
Number of space dimensions?
Quantum gravity?
Quantization of charge?
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Proliferation of parameters?
Matter-antimatter asymmetry?
Dark matter? Dark energy?

Success? Or "flavor problem"?

Kaon physics and *B* factories: SM picture of CP violation satisfactory at least at tree level in B^0 and B^+ decays. NP amplitudes < 10%, if any.

Success of the CKM picture rules out NP with a generic, natural flavor structure.

To keep the NP-scale in the TeV range, physics beyond the SM should have a highly fine-tuned flavor structure

…the end of the story?

(hopefully) Not

Limited control of hadronic uncertainties prevents checking consistency to better than 10-20%. Cannot exclude NP as a “perturbation” of CKM dynamics

Strange bottom: a new, uncharted territory of independent dynamics to be dissected and explored in full.

Capabilities of some of our best NP probes (fully leptonic *B* decays, invisible *K* decays..) not yet exhausted

Stubborn persistence of interesting 2σ-ish fluctuations in several processes

What you'll see

Arbitrary choice of topics that

✓show, or may show interesting fluctuations from expectations

✓*AND* will evolve significantly in the next 2-3 years.

My "vision" is short. And 2-3 years is the timescale for having results from whole Tevatron dataset and the first LHC run.

More detail on newer stuff

- New $B^0_s \rightarrow \mu\mu$ search from DØ (brand new for BF2010)
- New A_{SL} from DØ (brand new for BF2010)
- New sin2βs from CDF (brand new for BF2010)

What you won't see

Things that will probably need more than 2-3 years to undergo substantial (experimental) progress.

- Status of γ (see C. Jessop's talk in the afternoon)
- $B^{+} \to \tau\nu$ (see S.J. Sekula's and D. Mohapatra's talks in the afternoon)
- sin2β puzzles
- $b \to X_s \gamma$
- f_{Ds} puzzle
- …

The $B \to K\pi$ puzzle

CPV in decay

Most direct manifestation of CP non conservation: CP-conjugate states decay at different rates

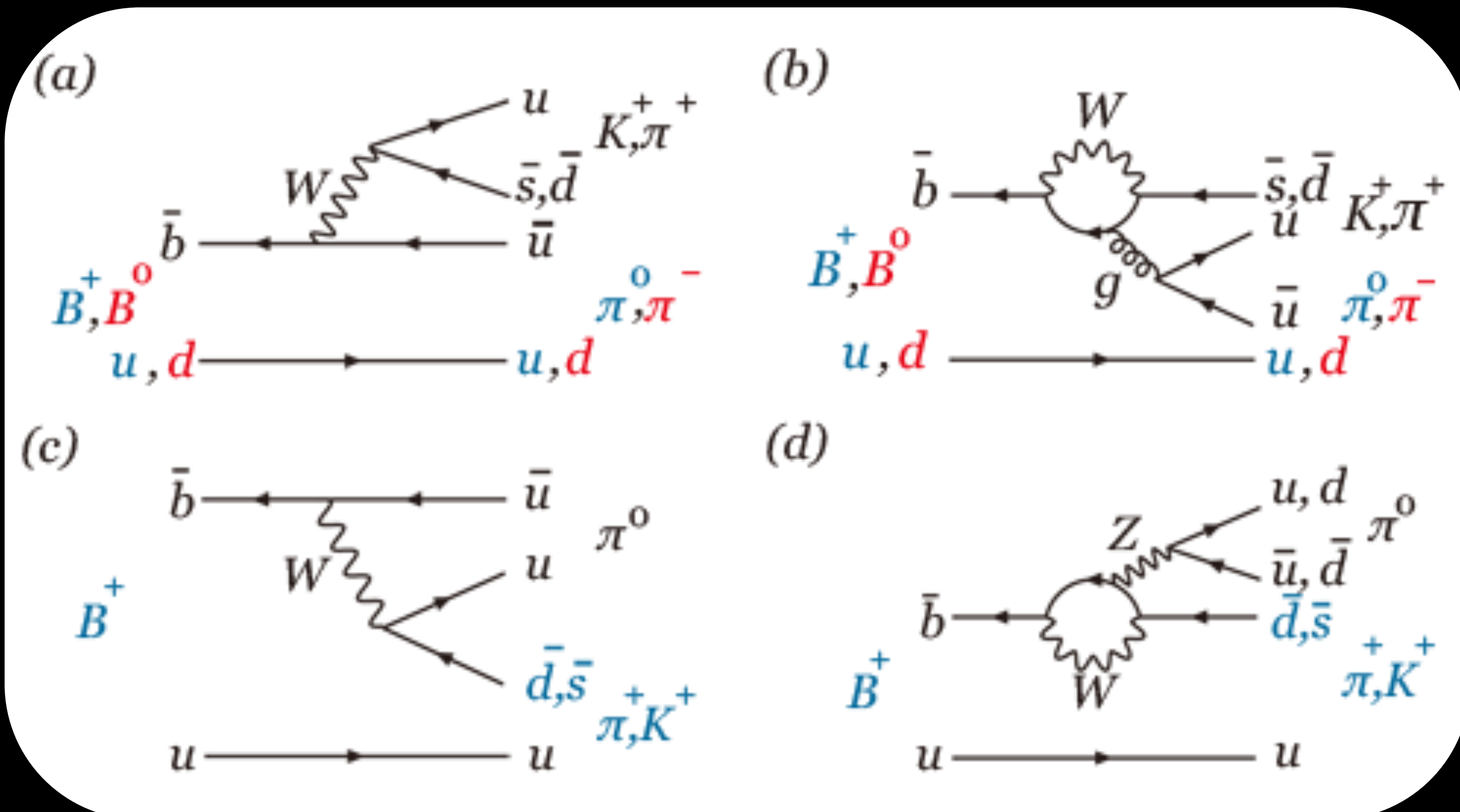
$$\Gamma\,(A \rightarrow B+C) \neq \Gamma\,(\overline{A} \rightarrow \overline{B}+\overline{C})$$

Need 2+ diagrams w/ different CKM *and strong phases*

Large A_{CP} easier to measure, but harder to interpret because implies large strong phases. QCD in non-perturbative regime makes it tough. Life is hard.

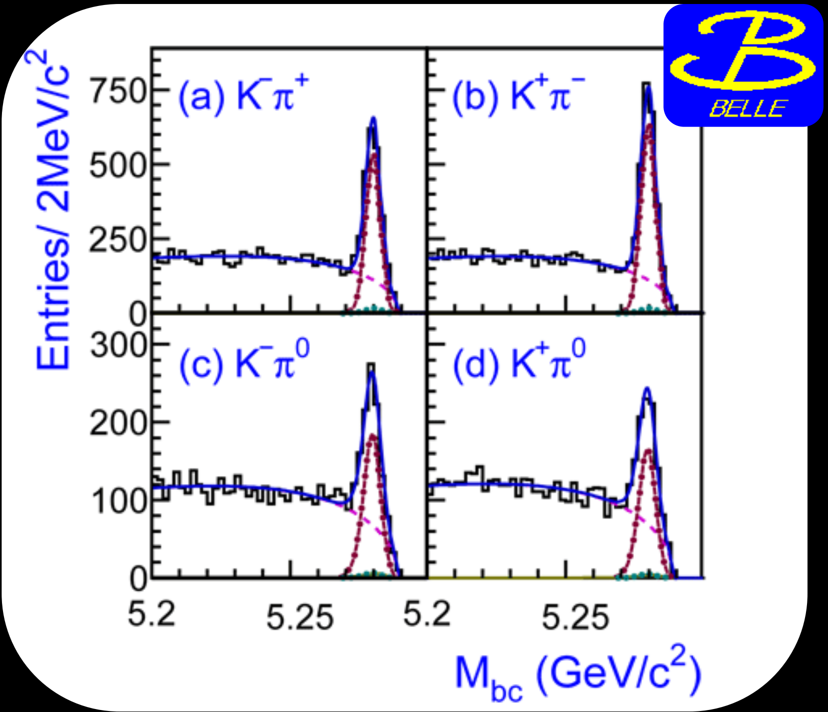
Workaround: use other decays mediated by same transitions to suppress unknowns in relative quantities (ratios, differences etc..)

$B^0 \rightarrow K^+\pi^-$ vs $B^+ \rightarrow K^+\pi^0$



The B→Kπ puzzle

* Lots of statistics
* Look at Kπ fin. states
* Distinguish with PID
* Fit event yields



$$\Delta\mathcal{A} \equiv \mathcal{A}_{K^\pm\pi^0} - \mathcal{A}_{K^\pm\pi^\mp} = +0.164 \pm 0.037$$

Effect is >4σ.

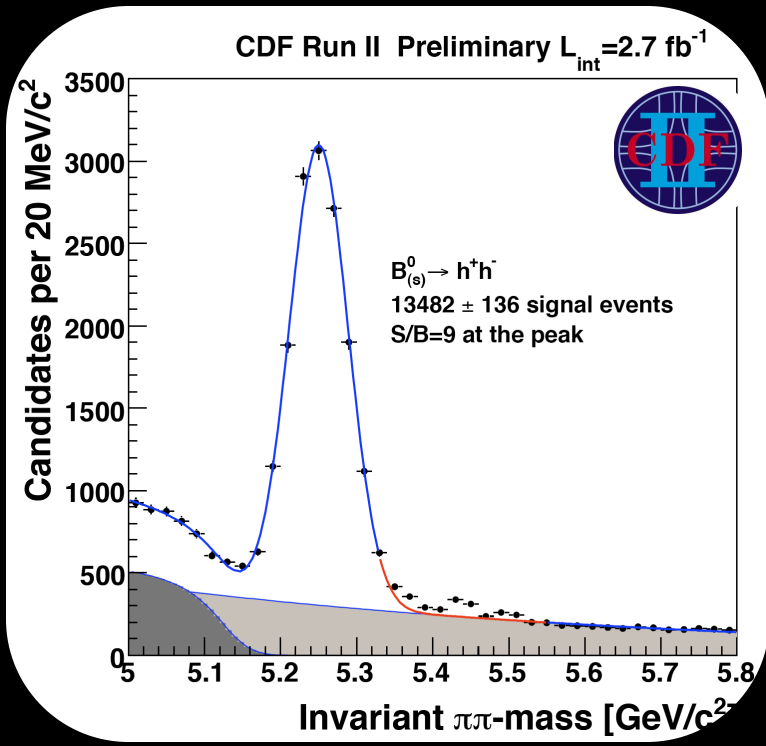
Nature 452, 332 (2008)

QCD or New Physics?

Amplitudes assumed suppressed play a stronger role than expected?

Experimental precision already high and limited by sistematics.

Waiting for theory



…with a little help from CDF or LHCb, which may complete the picture with $B^0_s \to K\pi$ and/or constrain penguin annihilation

PRL103, 031801 (2009)

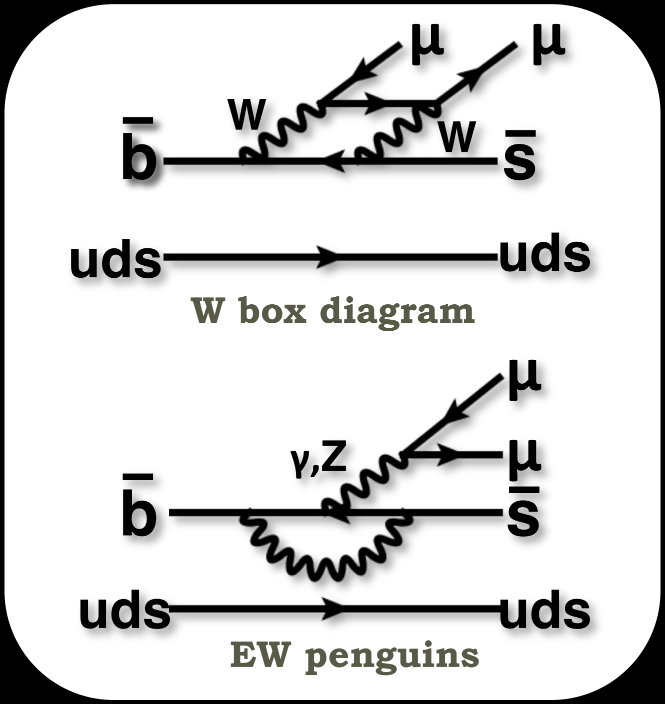
Flavor Changing Neutral Currents

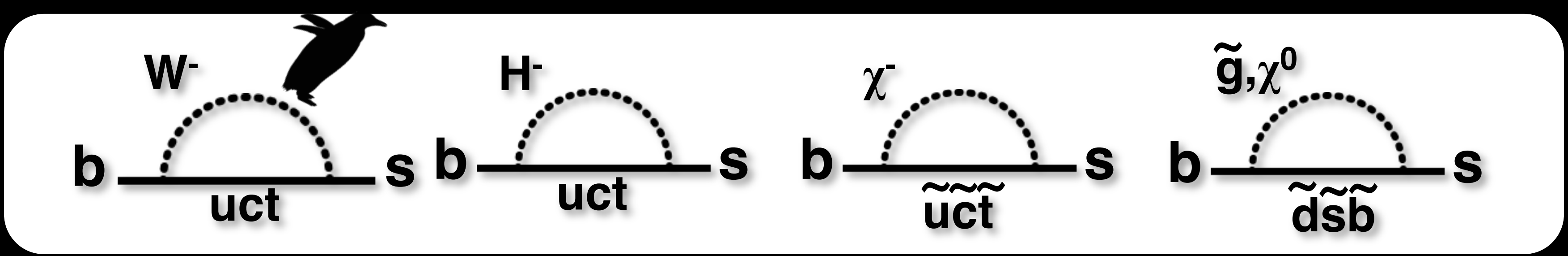
$b \rightarrow s\mu^+\mu^-$ - penguin galore

Suppressed in SM. Br ~ 10^{-6}

NP in penguin or box modifies decay-kinematics

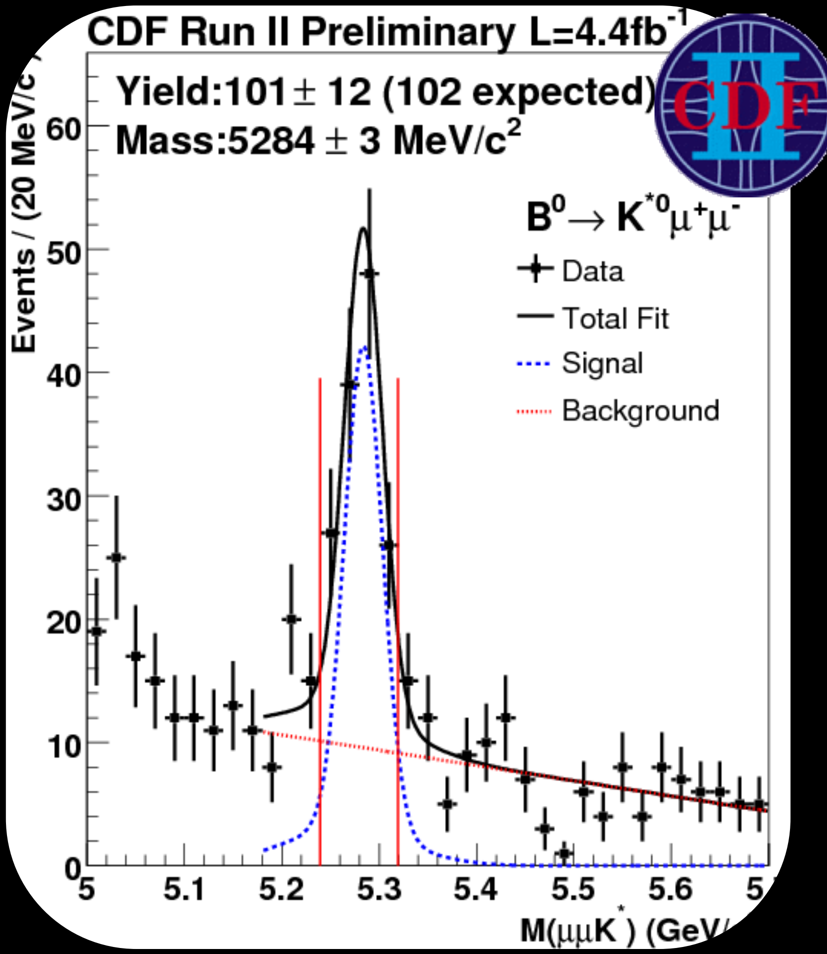
Pretty clean theoretically and experimentally.





$b \rightarrow s\mu^+\mu^-$ - analysis

- Need huge statistics
- Good muon acceptance
- Effective selection (PID)
- Strong control of detector acceptances

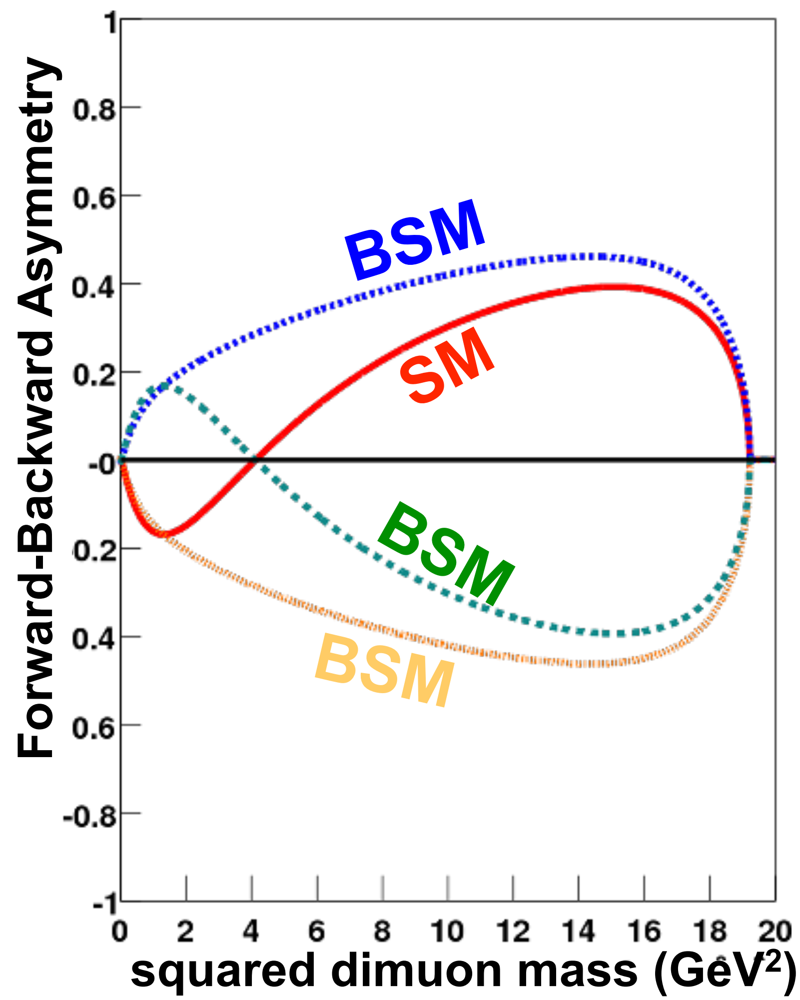


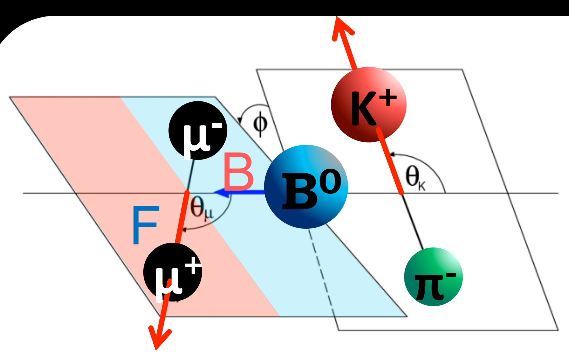
CDF Public Note 10047

$b \rightarrow s\mu^+\mu^-$ - A_{FB}

Final state hadrons.

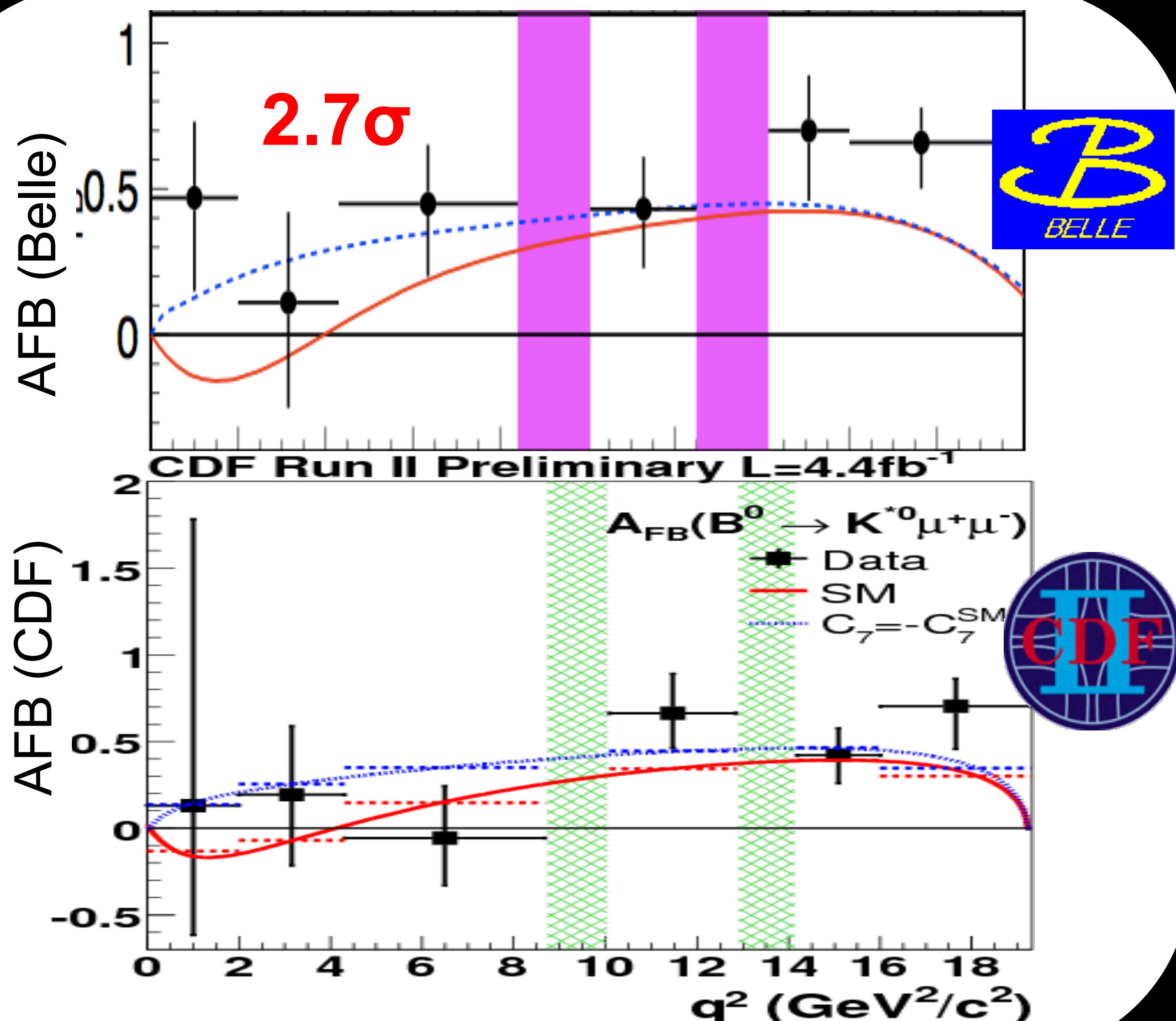
Theory uncertainties limited using relative quantities (μ distribution asymmetries) very sensitive to NP.





$B^0 \rightarrow K^{*0} \mu\ \mu$ decay plane

$b \to s\mu^+\mu^-$ - current status



CDF Public Note 10047

PRL103, 171801 (2009)

When the going get tough..

CDF already competitive. Add 2-3x statistics & improved analysis. World best in 2011.

DØ weighing in (?)

LHCb: 1200 events expected with 1 fb^{-1}.

Exclude SM at 4σ and <1 GeV^2 precision on zero-crossing point.

Stay tuned on this one.

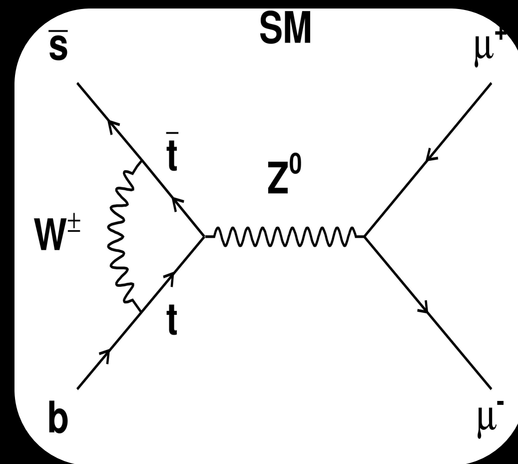
$B^0_s \to \mu^+\mu^-$ - *trivia*

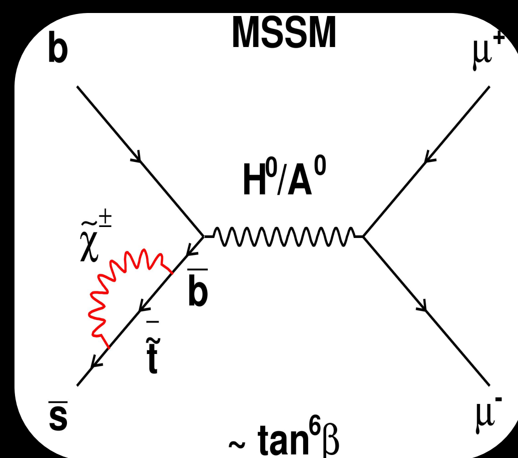
Gets all available suppressions in SM

All leptonic decay: robust SM prediction Br = $(3.42 \pm 0.54)\times10^{-9}$.

NP can enhance rate up to 100×.

Sensitive to a broad class of NP models, complementary to many TeV/LEP direct searches.





$B^0_s \to \mu^+\mu^-$ - the measurement

Collect as many dimuons as possible

The challenge: reject 10^6 background while keeping signal efficiency high.

Combine discriminating information (vertexing, lifetime, p_T, fragmentation) into NN.

Calibrate NN using data as much as possible and check background estimation in multiple control samples.

Open box.

Transform upper limit on number of signal events into Br by using reference mode ($B^+ \to J/\psi K^+$) and MC/data for relative efficiencies.

CDF results 3.7 fb^{-1}

	$\mathcal{B}(B_s \to \mu^+\mu^-)$ 90%	95%	$\mathcal{B}(B_d \to \mu^+\mu^-)$ 90%	95%
Expected $\mathcal{B}$	2.7×10^{-8}	3.3×10^{-8}	7.2×10^{-9}	9.1×10^{-9}
Observed $\mathcal{B}$	3.6×10^{-8}	4.3×10^{-8}	6.0×10^{-9}	7.6×10^{-9}

World-leading result.

$Br(B^0_s \to \mu\mu) < 4.3 \times 10^{-8}$ (95% CL)

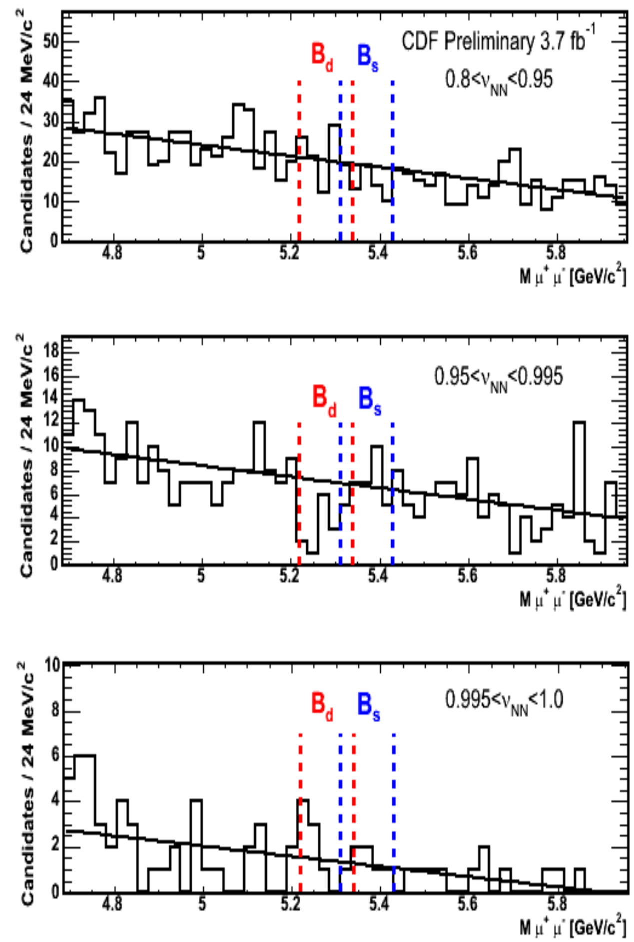
10*SM with 3.7 fb^{-1}.

This result CDF Note 9892,

2 fb^{-1} PRL100, 101802 (2008) topcite100+

0.78 fb^{-1} PRL93, 032001 (2008) topcite50+

Three slices of NN output



6 bckg expected, 7 evts observed

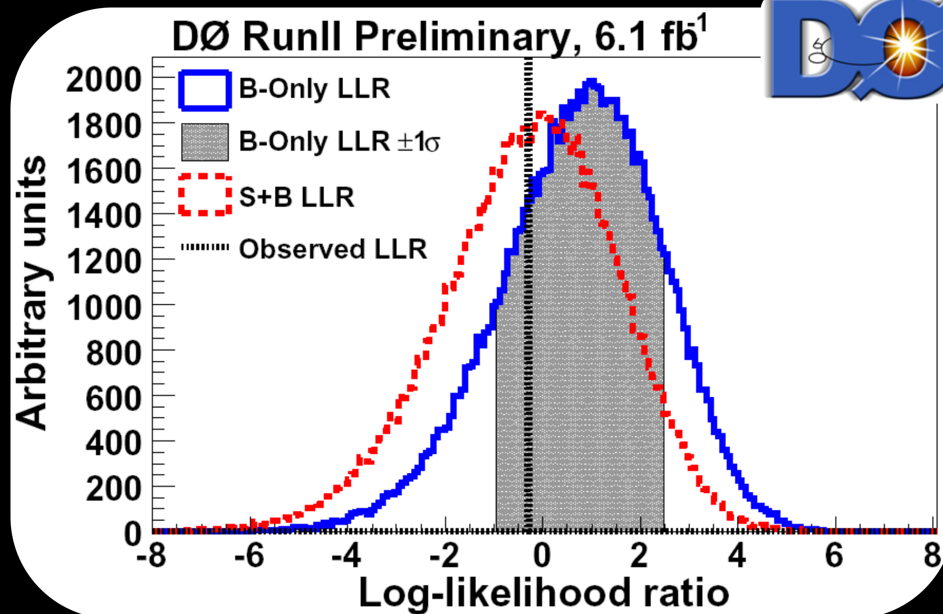
New for BF2010

DØ results 6.1 fb^{-1}

Analysis greatly improved and extended to 6.1 fb^{-1}

Increased acceptance: +10% muon-ID and +16% trigger

Signal region split in NN and mass bin for increased sensitivity.



New limit @ 95%C.L

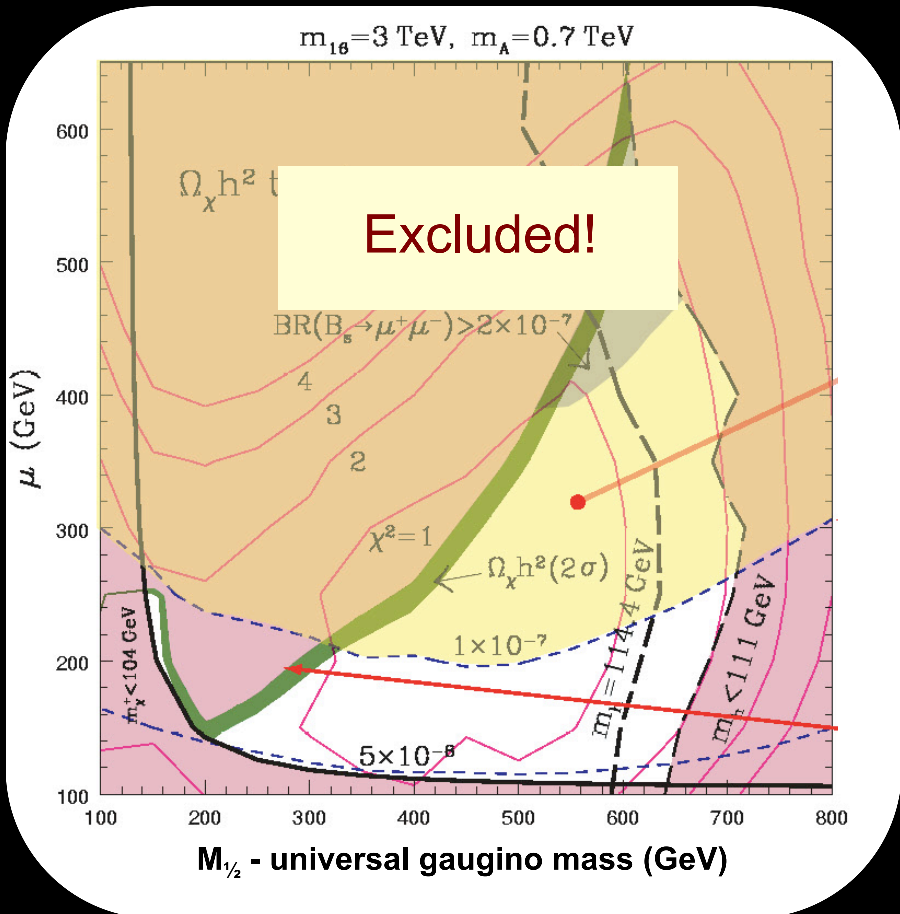
$Br(B^0_s \to \mu\mu) < 5.2 \times 10^{-8}$

(3.8×10^{-8} expected)

1.3 fb^{-1} PRD 76, 092001 (2007)

0.24 fb^{-1} PRL 94, 071802 (2005) topcite50+

$B^0_s \to \mu^+\mu^-$ - a broad impact



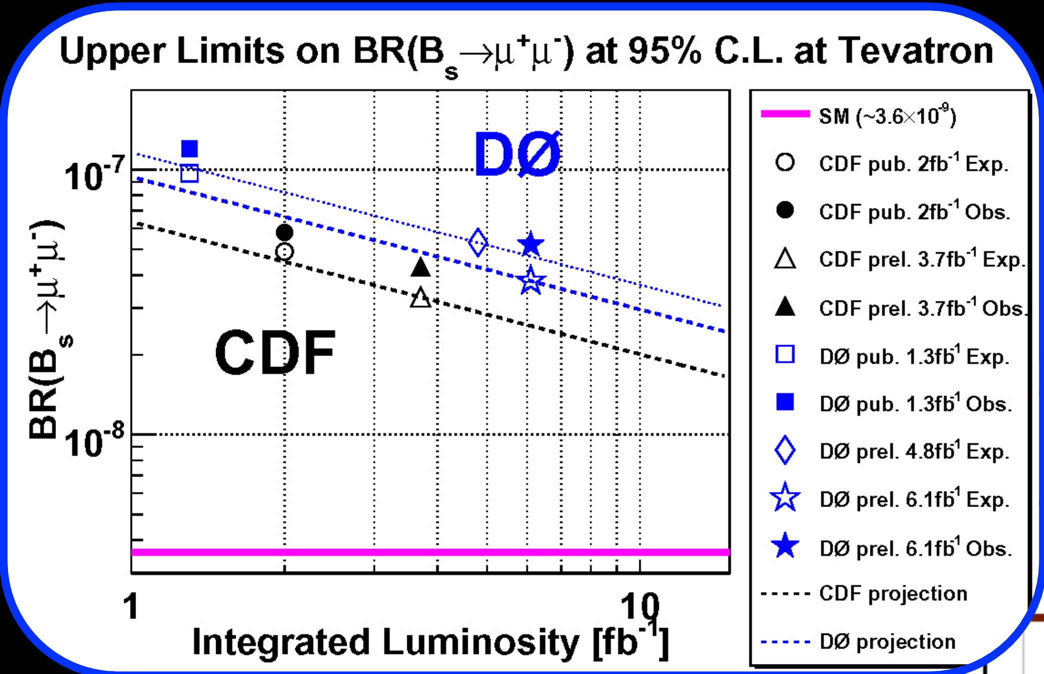
Lot of recent activity on implications for DM searches

$B^0_s \to \mu^+\mu$ *rate* and neutralino x-section depend on tan(β).

Bounds on Br($B^0_s \to \mu^+\mu$) reduce allowed space of parameters for DM

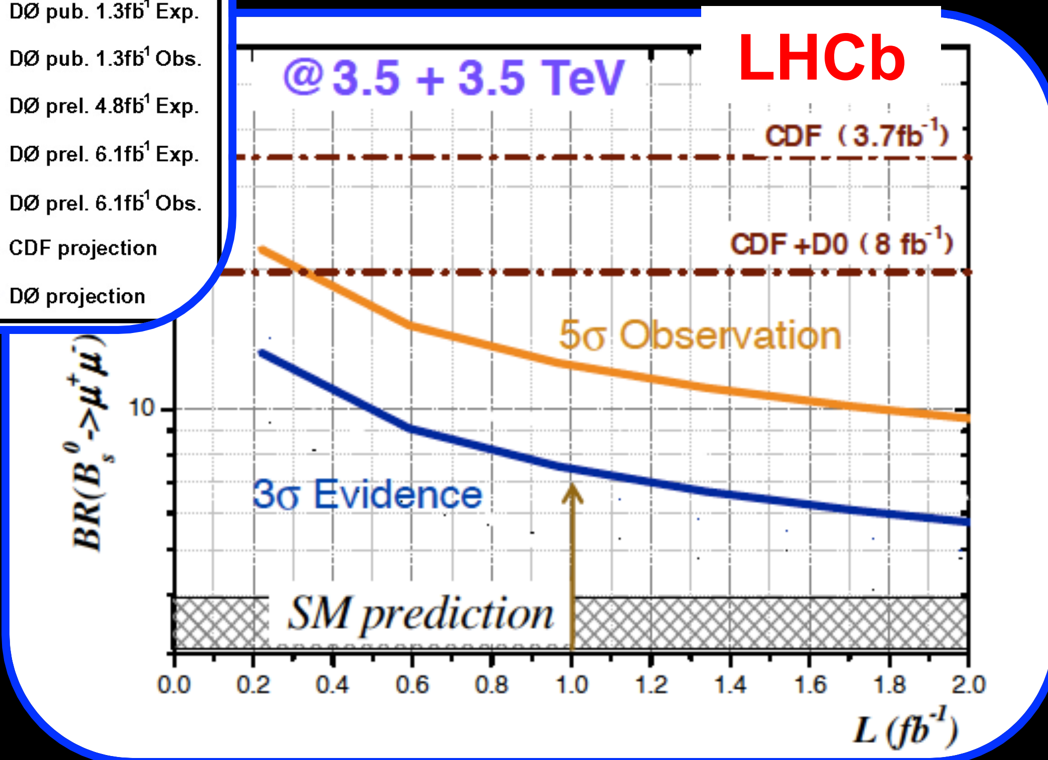
Strongly constrains specific SUSY models, e.g. SO(10) Dermisek et al. JHEP 0509, 029 (2005)

$B^0_s \rightarrow \mu^+\mu$ - year 2012



Competition may be tight. ATLAS and CMS may join

SM value won't be probed anytime soon, but eating-in last chunks of NP space.



New Physics in B^0_s mixing

Why *Strange Bottom?*

V On the Autonomy of B_s Dynamics

original paradigm: need B_d & B_s to determine all 3 angles

ϕ_2/α, ϕ_1/β from B_d vs. ϕ_3/γ from B_s

new paradigm: can get all angles from B_d

Furthermore NP in general will not obey SM relations between B and B_s decays

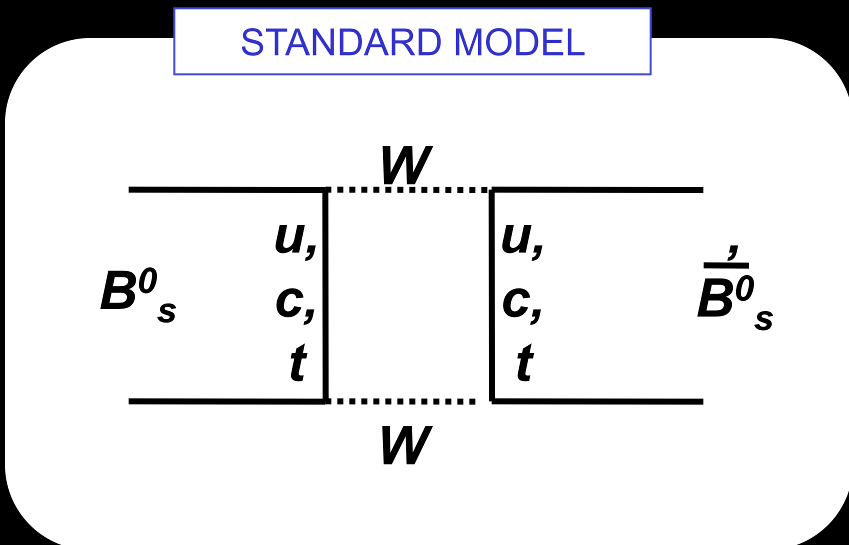
➡ B_s decays a priori independent chapter in nature's book on fundamental dynamics

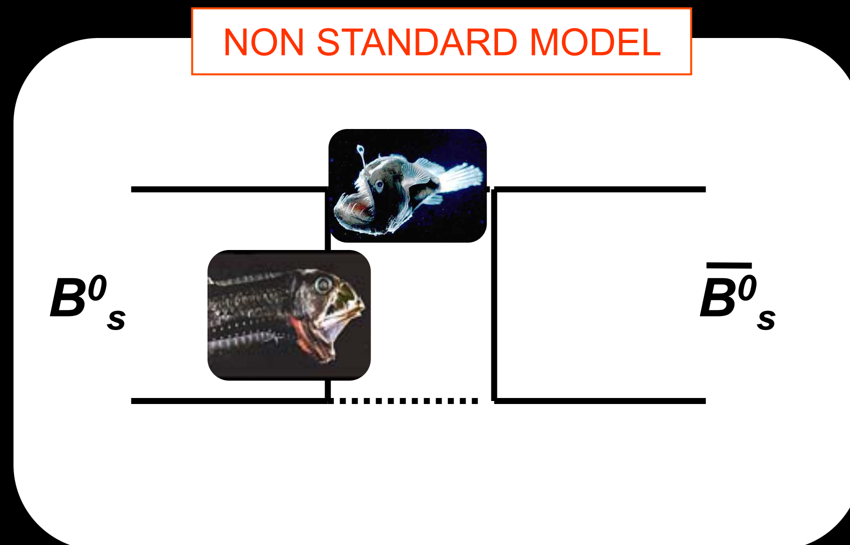
$B_s(t) \to \psi\phi, \psi\eta, \phi\phi$ not a repetition of lessons from B_d & B_u decays!

stolen from I. Bigi, CERN Theory Institute, 26/5/2008

Probing NP through flavor mixing

Neutral flavored mesons oscillate





Factorize BSM physics into a complex amplitude

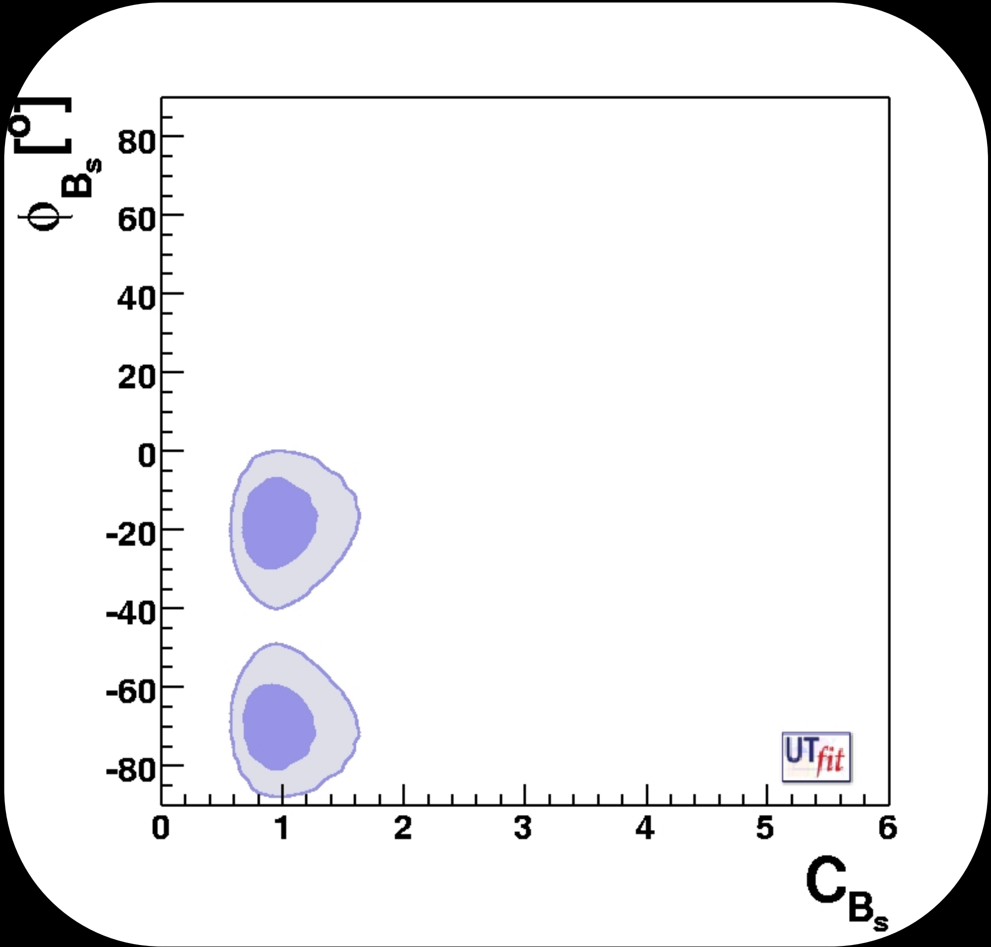
$$\frac{\langle M|H_{\mathrm{eff}}^{\mathrm{full}}|\bar{M}\rangle}{\langle M|H_{\mathrm{eff}}^{\mathrm{SM}}|\bar{M}\rangle} = C_M e^{2i\phi_M}$$

To constrain NP need to measure <u>strength and phase</u>

Why the phase?

Still largely unconstrained.

Large room for NP left unexplored



Anomalous like-sign dimuon charge asymmetry at DØ

(see D. Tsybychev talk for full details)

New for BF2010

A_{SL} – measurement concept

- *B* in $p\bar{p}$: strong, flavor-symmetric $p\bar{p} \rightarrow b\bar{b}$ pair-production
- *B* always produced in opposite-flavor pairs in the event
- 50% of *b* and $\bar{b}$ hadronize into neutral mesons: B^0 or B^0_s which undergo flavor-oscillations before decaying.
- 1.3% of times both *B* decay to μ. Muon charge tags flavor: μ^- from $\bar{b}$, μ^+ from *b*,
- $\mu^-\mu^-$ and $\mu^+\mu^+$ from *B* mean that oscillation occurred.
- Same oscillation prob. for *b* and $\bar{b}$ ➔ N(++) = N(- -)
- If N(++) ≠ N(- -) then CPV in mixing.
- CKM : CPV~10^{-4}. Enhancement indicates non-SM sources

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New for BF2010

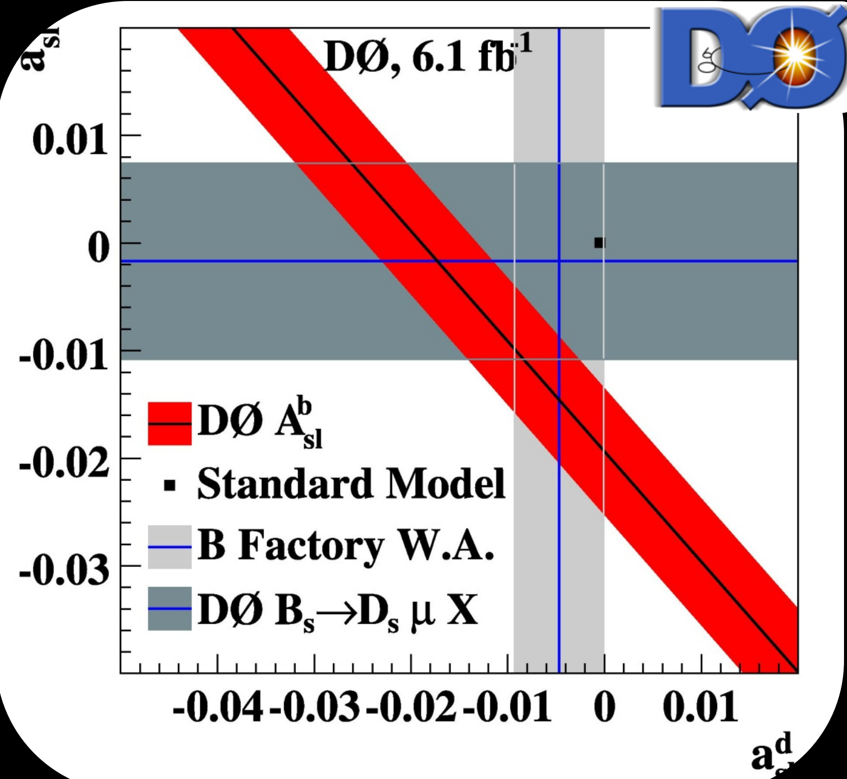
A_{SL} Result

$$A^b_{\rm sl} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}},$$

Assuming B^0_s and B^0 production fractions measured by CDF, CKM hierarchy predicts

$$A^b_{\rm sl}({\rm SM}) = (-2.3^{+0.5}_{-0.6}) \times 10^{-4},$$

Which is 3.2-sigma different from observed value:



$$A^b_{\rm sl} = -0.00957 \pm 0.00251\ ({\rm stat}) \pm 0.00146\ ({\rm syst})$$

arXiv:1005.2757

New for BF2010

Implications on B^0_s mixing

$$A^b_{\rm sl} \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}} = \underbrace{(0.506 \pm 0.043) a^d_{\rm sl}}_{B^0 \text{ mixing}} + \underbrace{(0.494 \pm 0.043) a^s_{\rm sl}}_{B^0_s \text{ mixing}}.$$

Using the WA value for a_{sl}^d (B factories) extract a_{sl}^s from which the phase ϕ_s can be inferred,

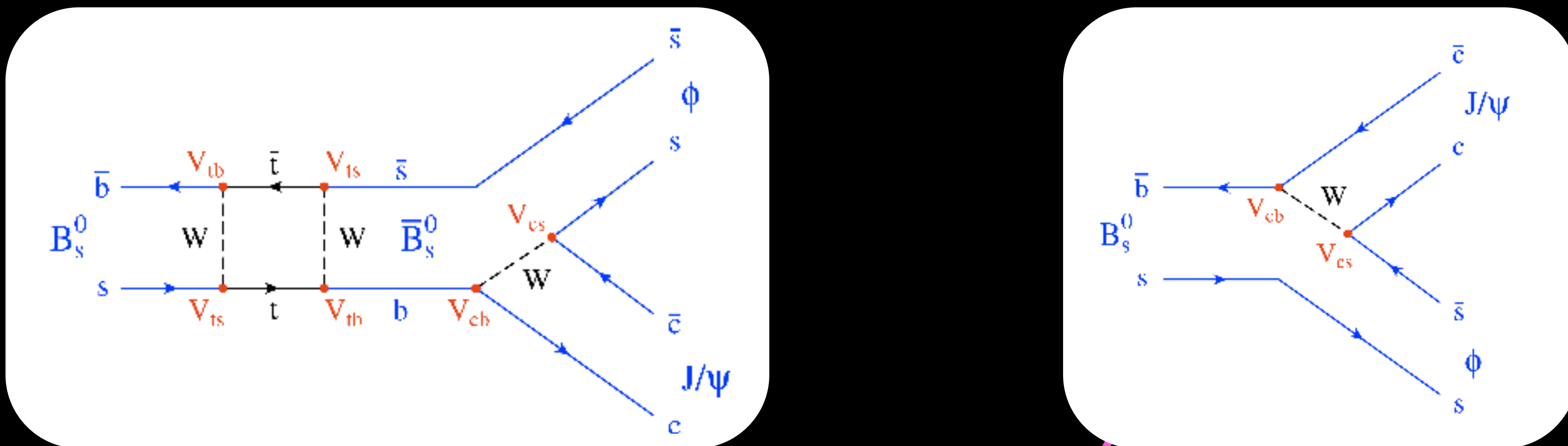
$$a^s_{\rm sl} = -0.0146 \pm 0.0075. \qquad a^q_{\rm sl} = \frac{\Delta\Gamma_q}{\Delta M_q} \tan\phi_q,$$

Discrepancy reduced at the ~2.5σ by experimental uncertainties on fragmentation fractions. arXiv:1005.2757

But in same direction/size as observed in $B^0_s \rightarrow J/\psi\phi$

Measurement of B^0_s mixing phase through $b \to \bar{c}cs$ *transitions*

$B^0_s \to J/\psi\phi$ - the golden probe



Mixing phase sensitive to NP

Tree $b \to c\bar{c}s$ phase ≈ 0

Time-evolution: $2\beta_s = -\arg[\underbrace{(V_{tb}V^*_{ts})^2}/\underbrace{(V_{cb}V^*_{cs})^2}]$

CKM hierarchy predicts 2βs tiny with ~zero theory error.
Any significant deviation is golden probe for new physics entering the box.

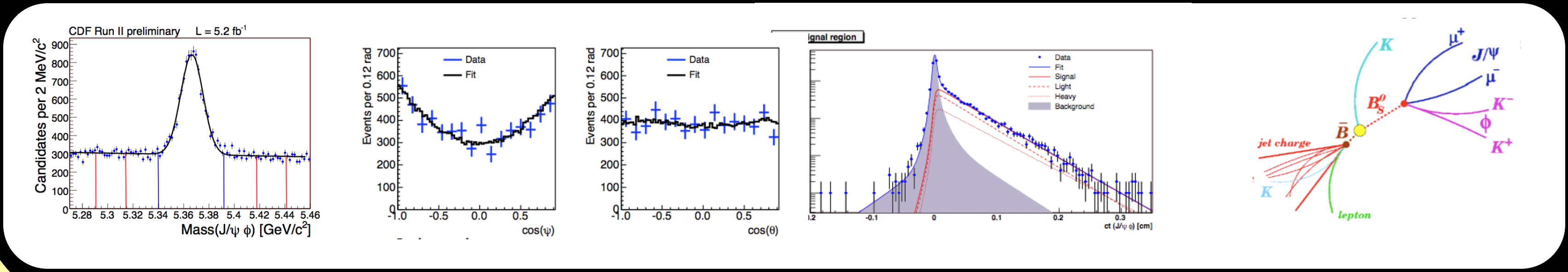
The analysis at a glance

Dimuon trigger

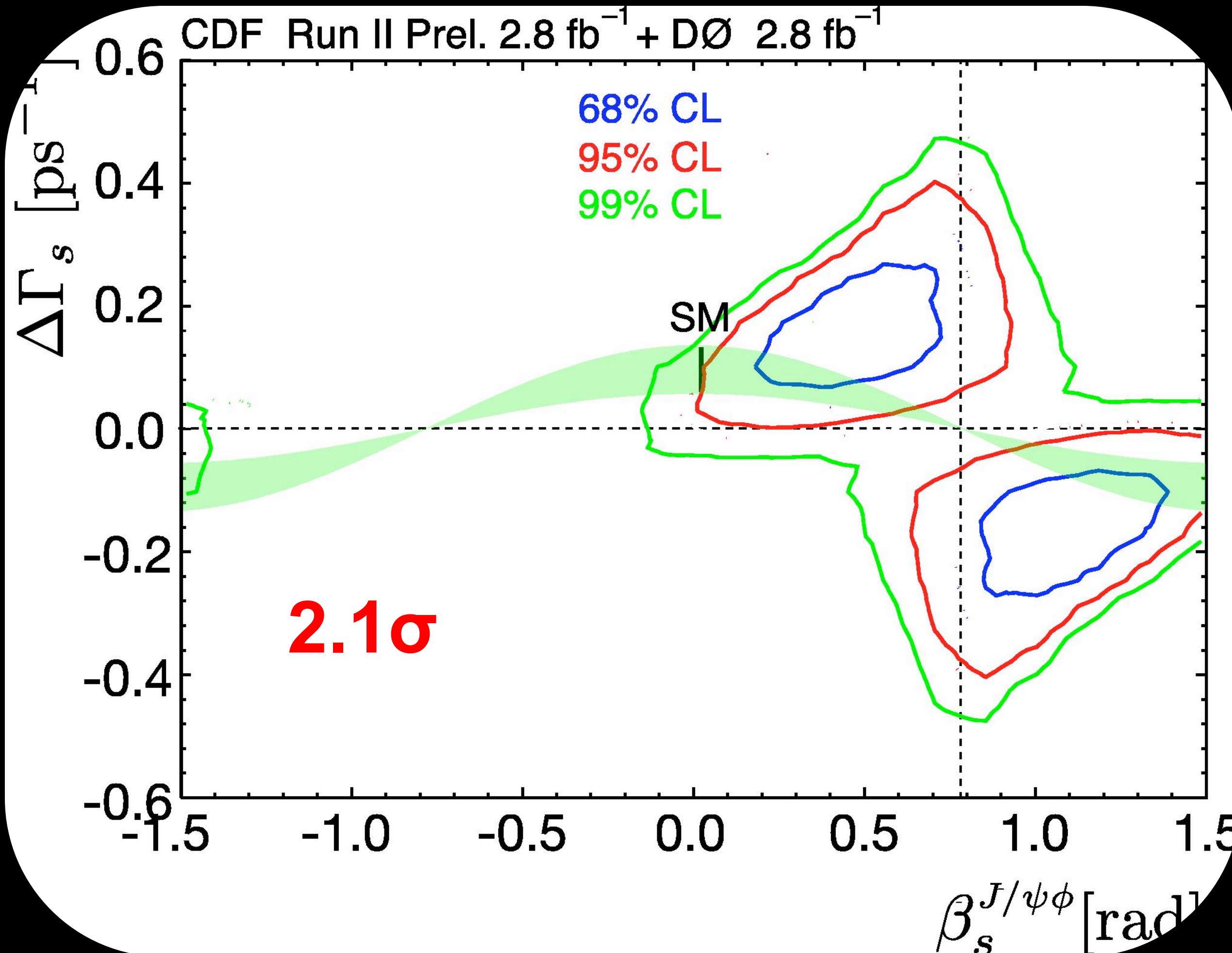
NN selection

Joint fit to mass, angles, decay-time and production flavor distributions

Mass to separate signal from bckg	Angles to separate CP-even/odd	Decay time to know time evolution	Flavor tagging to separate B from Bbar



Current experimental status



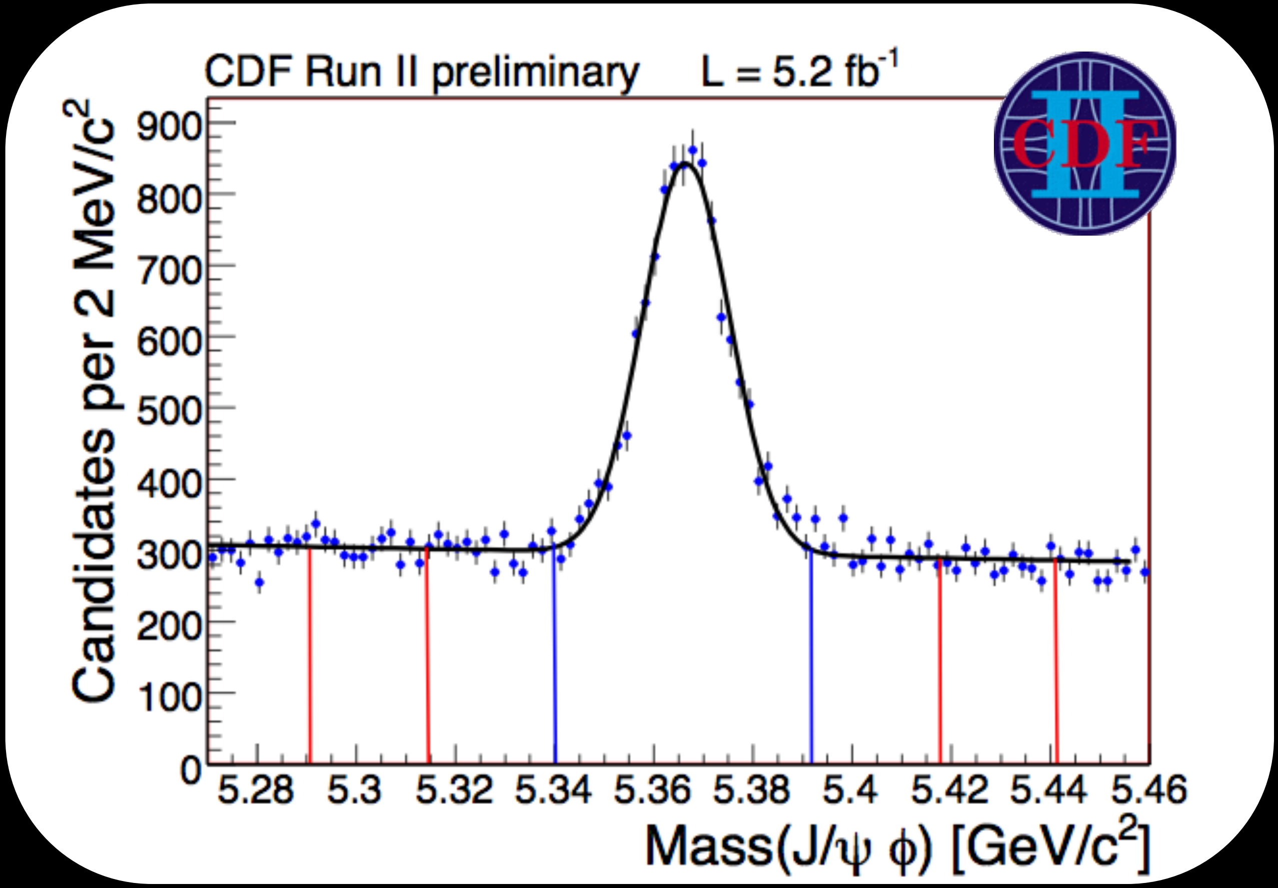
PRL101 161802 (2008) topcite100+
PRL101, 241801 (2008) topcite100+
http://tevbwg.fnal.gov/results/Summer2009_betas/

New CDF update with 5.2 fb^{-1}

New for BF2010

Signal

Selection optimized by minimizing the expected uncertainty on the phase as measured in pseudo-exp.

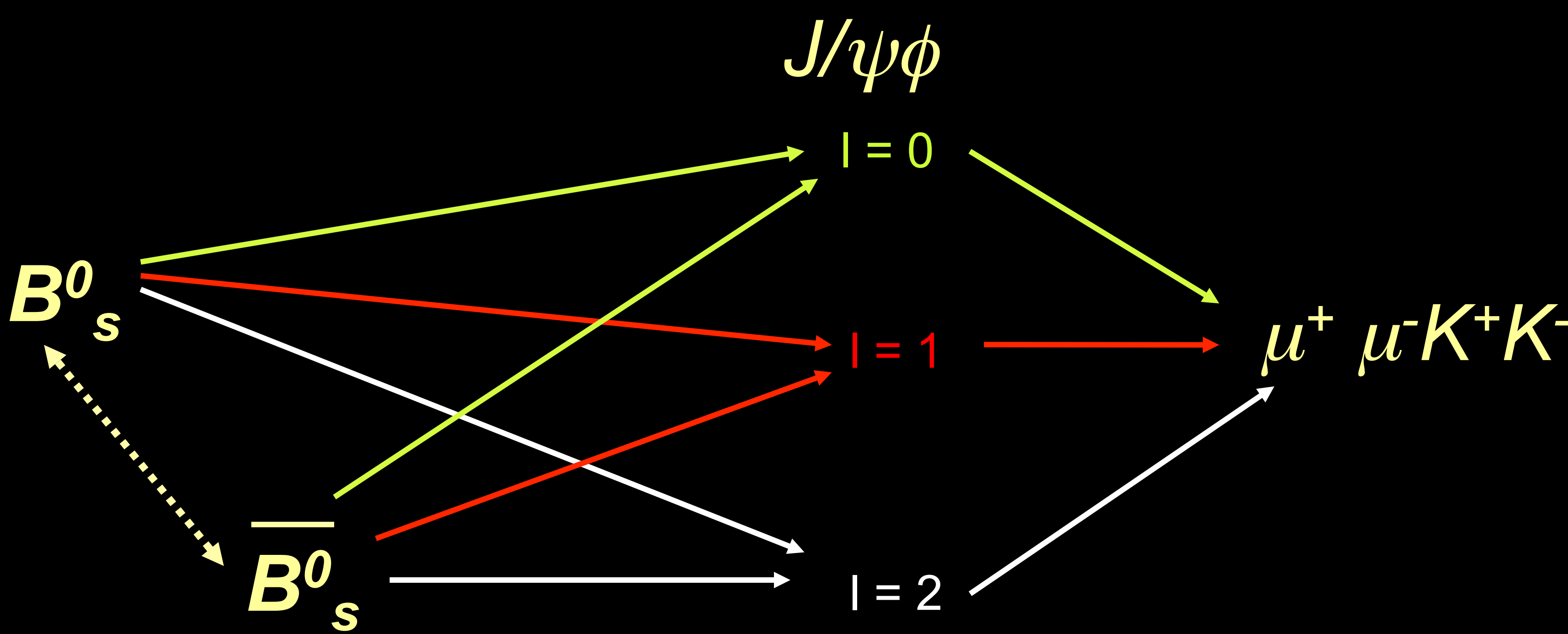


6500 signal decays

New for BF2010

CP composition

B^0_s (pseudoscalar) $\rightarrow J/\psi$(vector) ϕ (vector).



Exploit different dependence on phase between *CP*-even *and* *CP*-odd. Angular correlations to separe of CP-components.

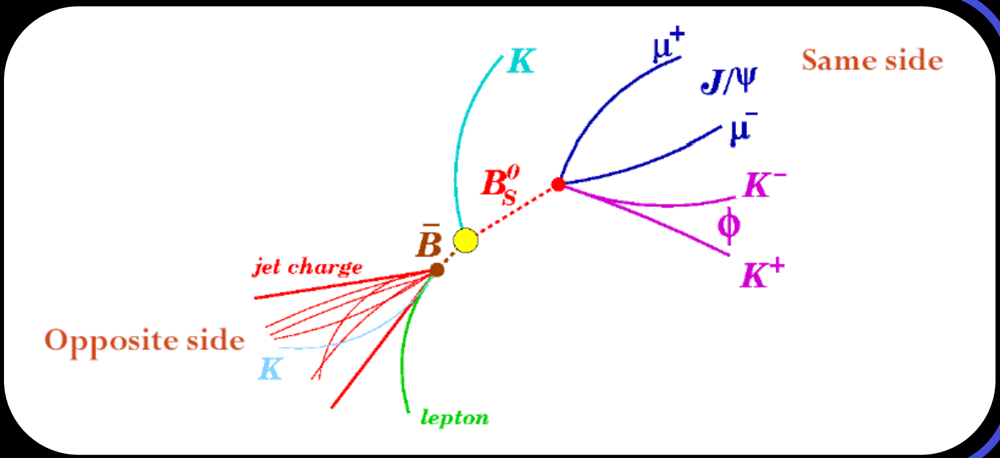
New for BF2010

Production-flavor

Greater sensitivity to the mixing phase if production flavor is inferred.

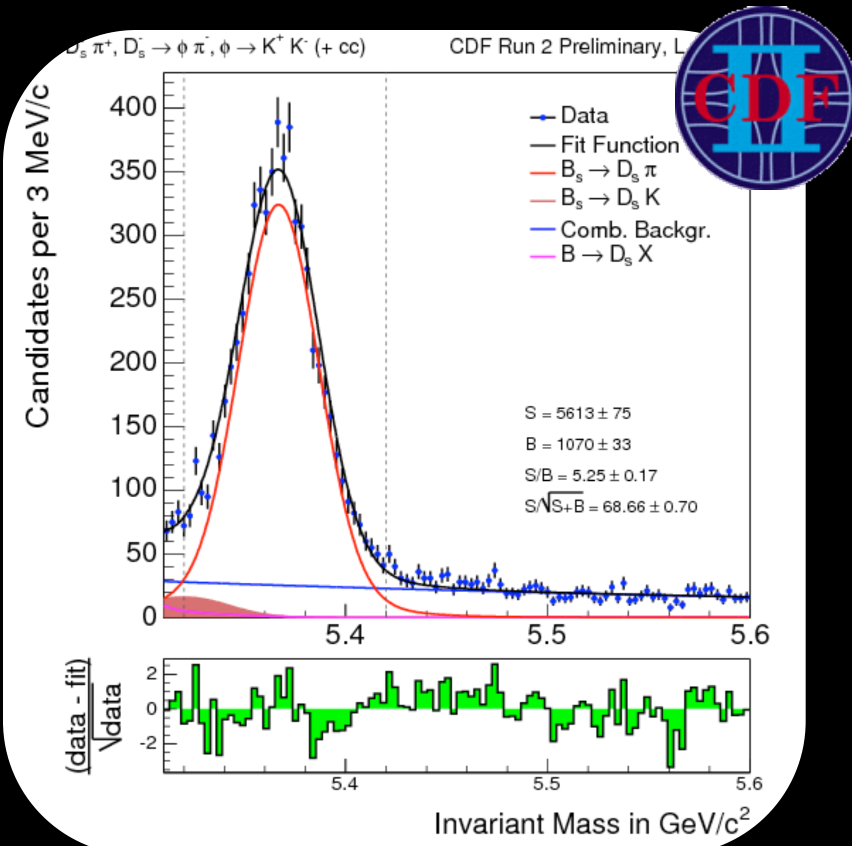
Exploit flavor-charge correlations of tracks produced in the fragmentation and decay.

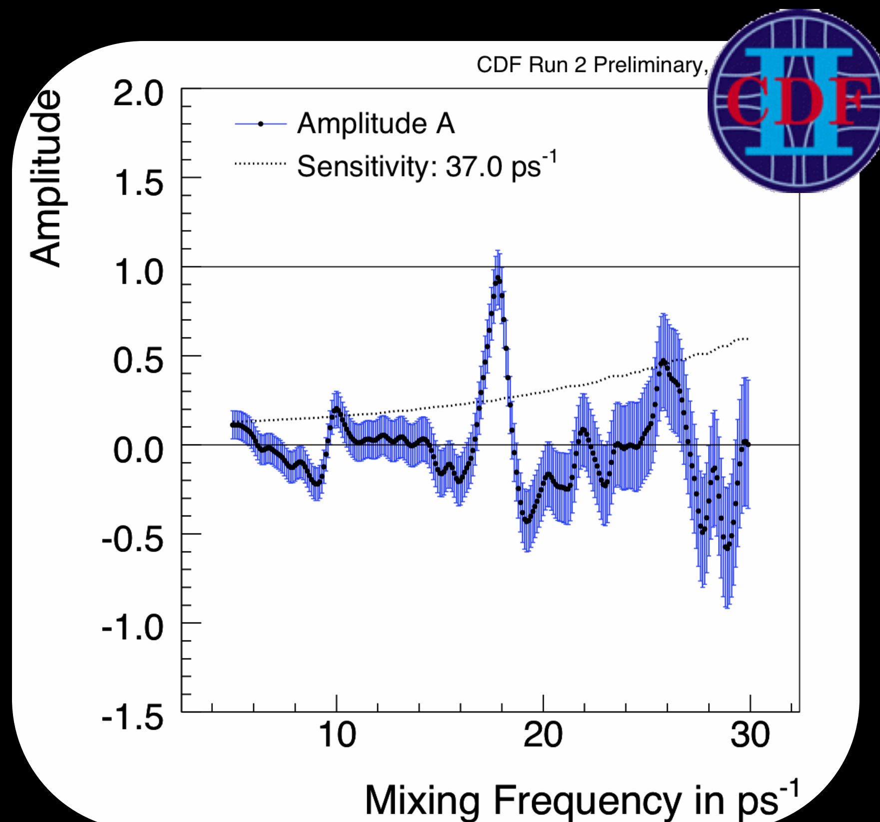
Total $\varepsilon D^2 \sim 4\%$



New for BF2010

Calibrating production-flavor





SSKT fully recalibrated in data through new mixing analysis

$\Delta m_s = 17.79 \pm 0.07\ ps^{-1}$ (stat. only)

$\epsilon \mathcal{A}^2 D^2 \approx 3.2 \pm\ 1.4\ \%$

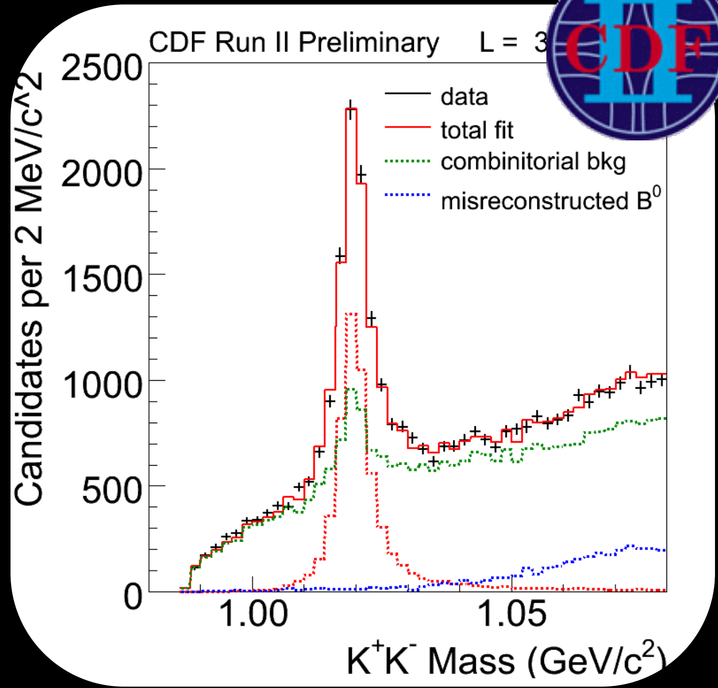
New for BF2010

Non-ϕ KK contributions

$B^0_s \rightarrow J/\psi KK$ decays (non resonant or f^0) can bias the phase measurement.

Included their contribution in full fit.

Non-ϕ component < 7% at 95%CL



Final results

New for BF2010

For starters

$$
\begin{aligned}
c\tau_s &= 458.6 \pm 7.5\ (\mathrm{stat.}) \pm 3.6\ (\mathrm{syst.})\ \mu\mathrm{m} \\
\Delta\Gamma &= 0.075 \pm 0.035\ (\mathrm{stat.}) \pm 0.01\ (\mathrm{syst.})\ ps^{-1} \\
|A_{\parallel}(0)|^2 &= 0.231 \pm 0.014\ (\mathrm{stat}) \pm 0.015\ (\mathrm{syst.}) \\
|A_0(0)|^2 &= 0.524 \pm 0.013\ (\mathrm{stat}) \pm 0.015\ (\mathrm{syst.}) \\
\phi_{\perp} &= 2.95 \pm 0.64\ (\mathrm{stat}) \pm 0.07\ (\mathrm{syst.})
\end{aligned}
$$

World-leading measurements of B^0_s lifetime, decay-width difference and decay-polarization

(soon Belle@Y(5S) will help here – see talk by D. Mohapatra)

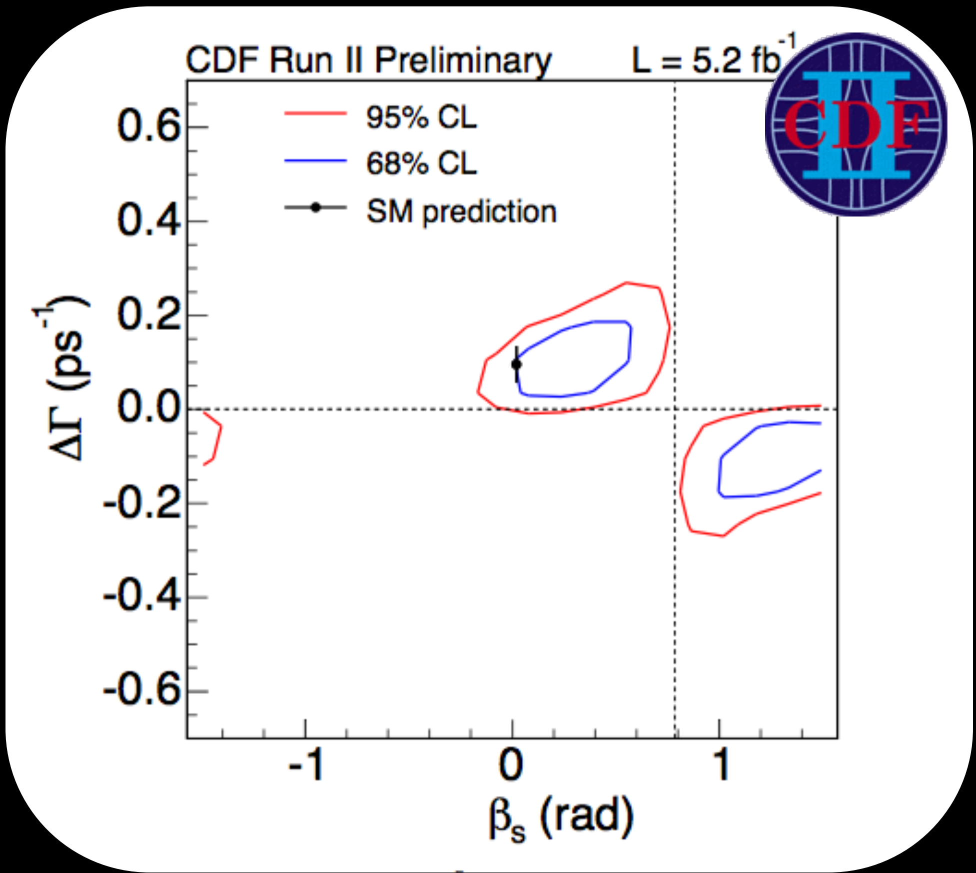
New for BF2010

Mixing phase

Allowed region for phase greatly reduced

Two solutions clearly separated.

Unfortunately the contour moved toward SM…



P-value = 44% wrt SM

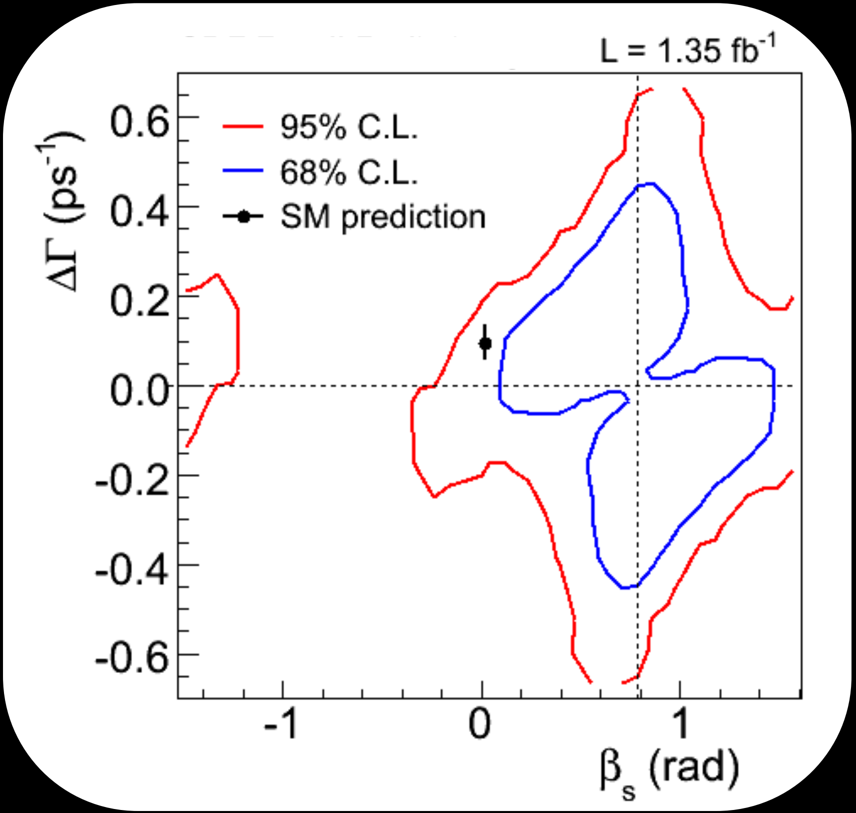
βs in [0.0, 0.5] U [1.1, 1.5] at 68% CL (one-dimensional)

βs in [-0.1, 0.7] U [0.9, $\pi/2$] U [$-\pi/2$, -1.5] at 95% CL (one-dimensional)

Comparison

New for BF2010

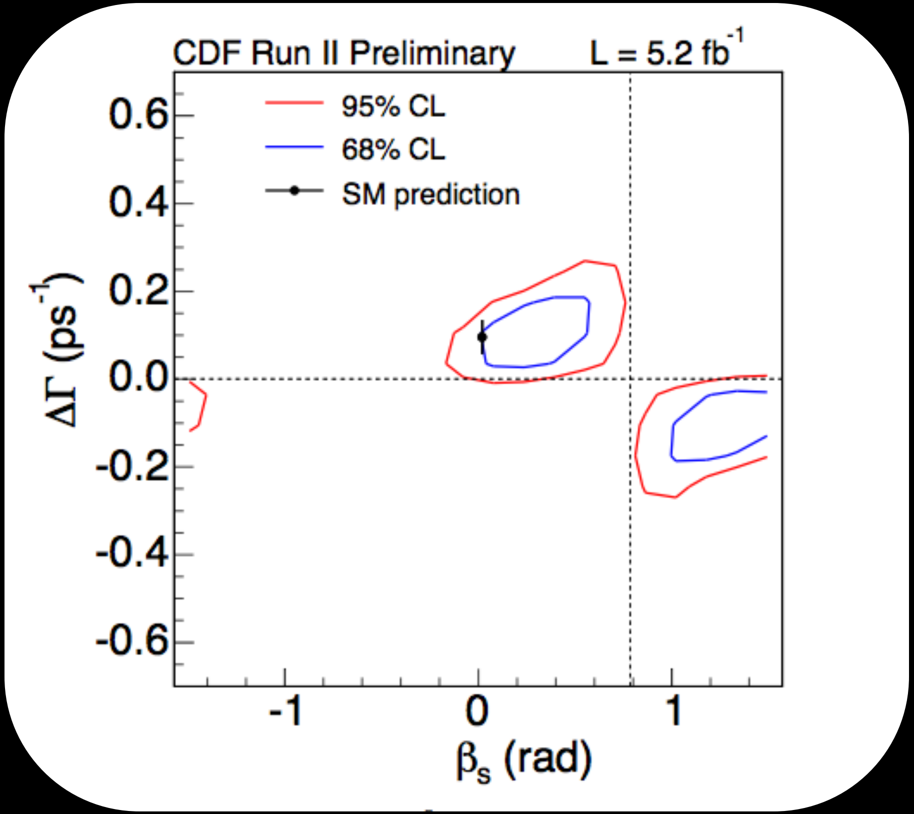
Something old…



P-value = 15% wrt SM

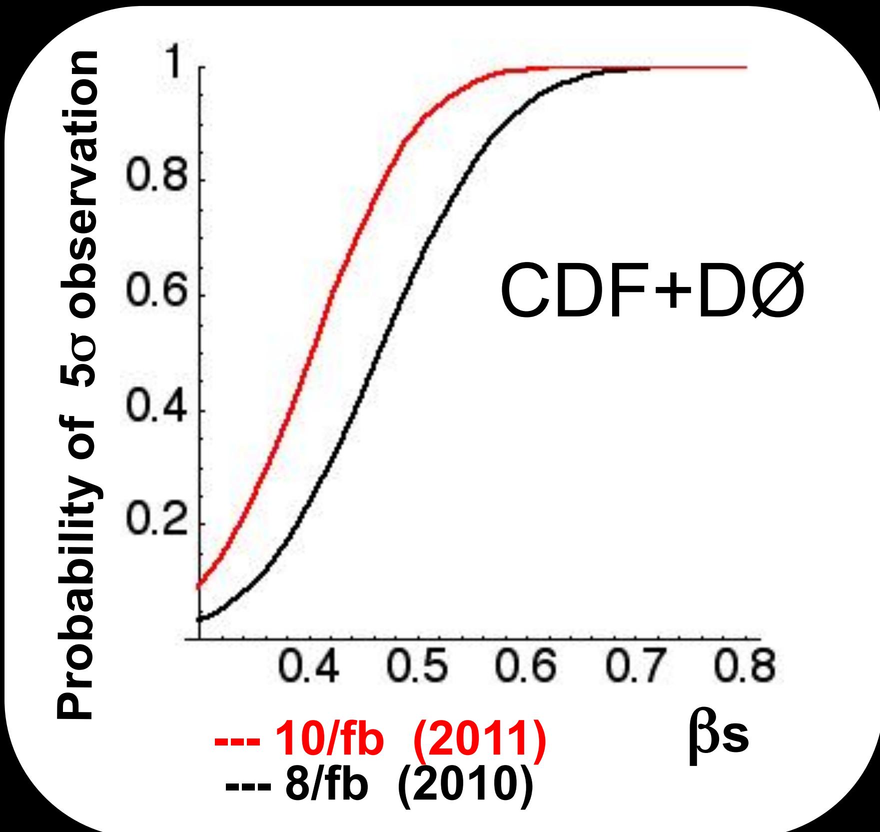
PRL101 161802 (2008) topcite100+

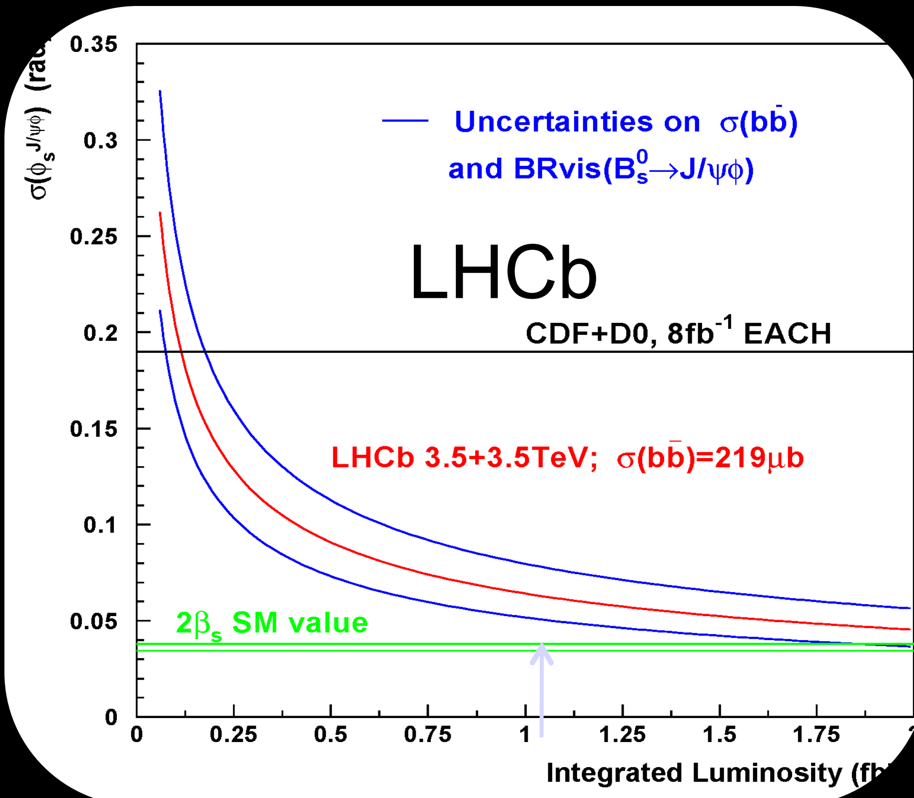
Something new…



P-value = 44% wrt SM

Getting hot





Tevatron 2012: discover or exclude NP in wide range of phases.
LHCb competitive (if everything turns out as expected)

So, what's the big picture?

Main Entry: ¹**ten·sion**

Pronunciation: \'ten(t)-shən\

Function: *noun*

Etymology: Middle French or Latin; Middle French, from Latin *tension-*, *tensio*, from *tendere*

Date: 1533

1 a : the act or action of stretching or the condition or degree of being stretched to stiffness : TAUTNESS **b** : STRESS 1b

2 a : either of two balancing forces causing or tending to cause extension **b** : the stress resulting from the elongation of an elastic body

3 a : inner striving, unrest, or imbalance often with physiological indication of emotion **b** : a state of latent hostility or opposition between individuals or groups **c** : a balance maintained in an artistic work between opposing forces or elements

4 : a device to produce a desired tension (as in a loom)

— **ten·sion·al** \'ten(t)-sh(ə-)nəl\ *adjective*

— **ten·sion·less** \'ten(t)-shən-ləs\ *adjective*

Poisson + QCD……. or BSM ?

Several interesting fluctuations.

None particularly significant alone.

Just a combination of statistics and poorly known hadronic uncertainties?

Perhaps.

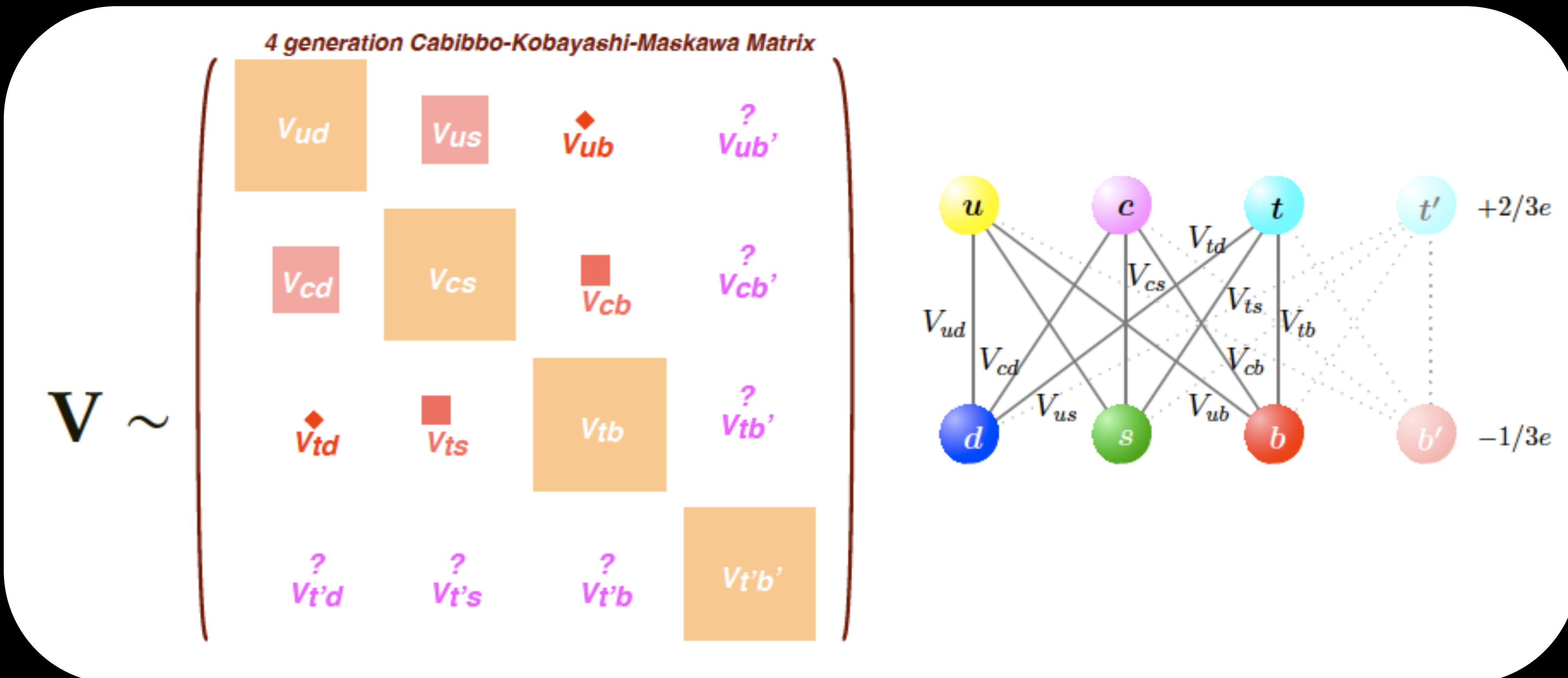
If taken as first hints of BSM, all fluctuations fit pretty naturally in coherent patterns

* Warped extra-dimensions? *(don’t ask)*

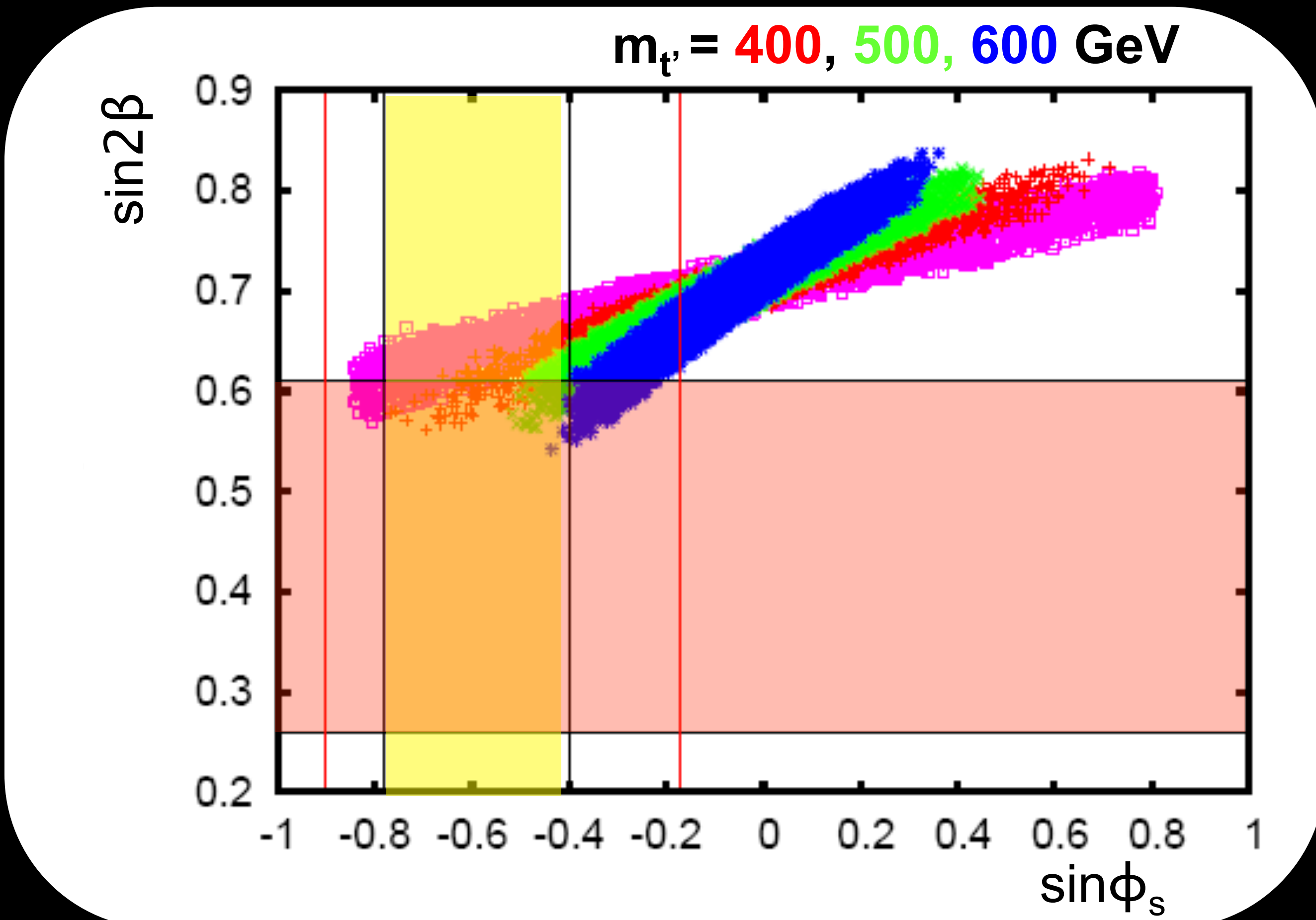
* Two Higgs doublet model for the top quark? *(don’t ask)*

* A 4th generation of heavy quarks (t’, b’)? *(don’t ask)*

SM4


4 generation Cabibbo-Kobayashi-Maskawa Matrix
V ~
Vud
Vus
Vub
Vub'
Vcd
Vcs
Vcb
Vcb'
Vtd
Vts
Vtb
Vtb'
Vt'd
Vt's
Vt'b
Vt'b'
?
u
c
t
t'
+2/3e
d
s
b
b'
−1/3e
Vud
Vcd
Vus
Vcs
Vtd
Vts
Vcb
Vub
Vtb

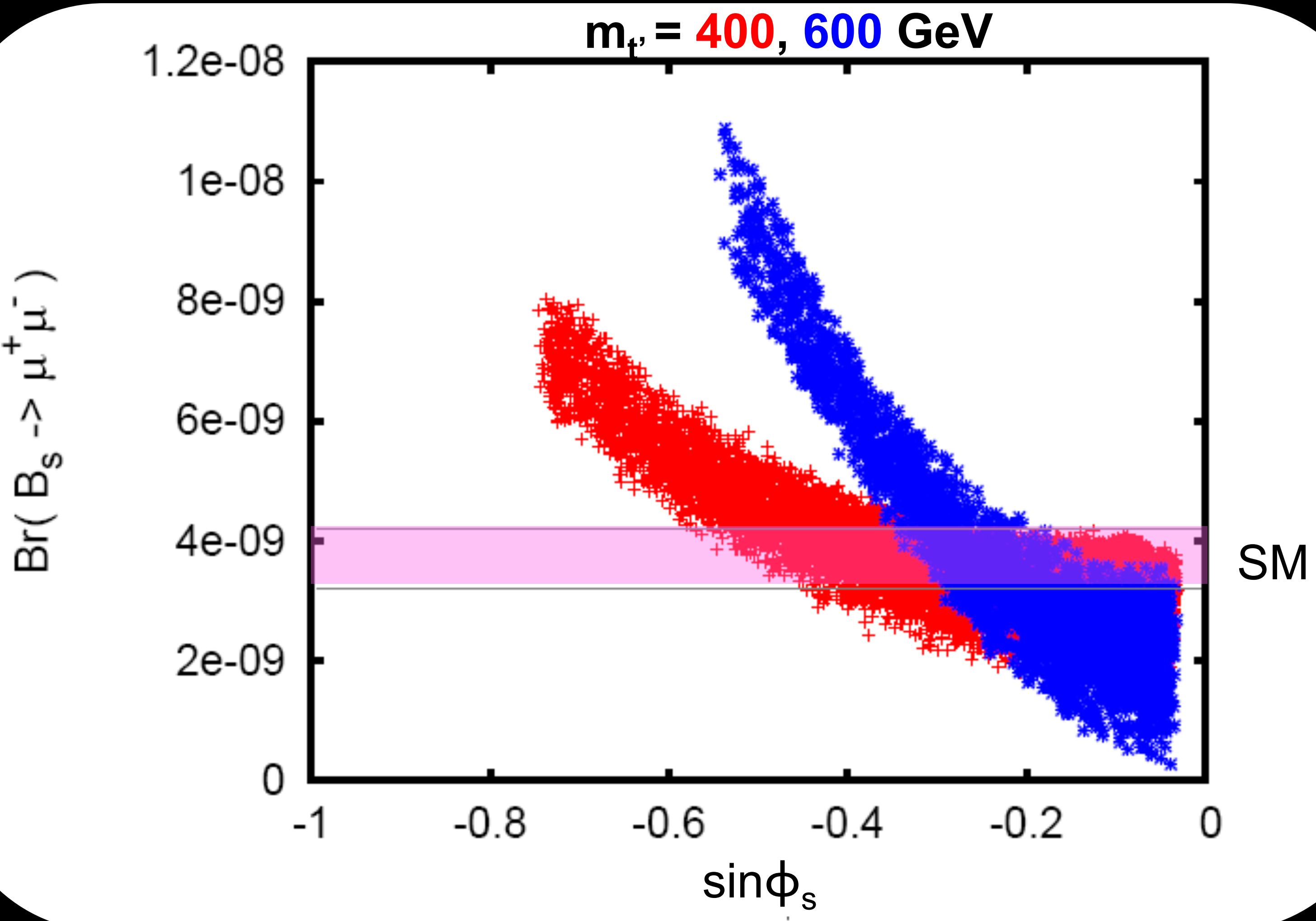
SM4



1-sigma from CDF+DØ

1-sigma from Babar+Belle

SM4


$m_{t'}$ = 400, 600 GeV
1.2e-08
1e-08
8e-09
6e-09
4e-09
2e-09
0
-1
-0.8
-0.6
-0.4
-0.2
0
Br(B_s -> $\mu^+\mu^-$)
$\sin\phi_s$
SM

Concluding remarks

CKM ansatz+flavor measurements of past 20+ years: a great success for the Standard Model.

A deep depression for us…

Desperately hanging to a couple of fluctuations?

Next 2-3 years crucial to determine whether we are seeing first whimpers of BSM or we all will die of MFV.

The Tevatron has and will have a key role.

Hopefully challenged soon by LHCb

The end

$B^0_{(s)} \to h^+h'^-$ - a model independent NP test

Unitarity of CKM matrix: $\mathrm{Im}(V_{ub}^* V_{us} V_{cb} V_{cs}^*) = -\mathrm{Im}(V_{ub}^* V_{ud} V_{cb} V_{cd}^*)$,

implies a relation between differences of CP-rates that is valid only in the SM. Unambiguous check if DCPV is induced by NP or by SM amplitudes.

$$\Gamma(\overline{B}^0 \to K^-\pi^+) - \Gamma(B^0 \to K^+\pi^-) = \Gamma(B_s^0 \to K^-\pi^+) - \Gamma(\overline{B}_s^0 \to K^+\pi^-)$$

We measure:

$$\frac{\Gamma(\overline{B}^0 \to K^-\pi^+) - \Gamma(B^0 \to K^+\pi^-)}{\Gamma(\overline{B}_s^0 \to K^+\pi^-) - \Gamma(B_s^0 \to K^-\pi^+)} = -0.83 \pm 0.41(stat.) \pm 0.12(syst.)$$

(-1 in the SM)

Still limited by statistics. Now, with ~5x data on tape, may have real chance to probe NP in these decays.

$B^0_s \to \mu^+\mu^-$ - the measurement

Latest result (summer 2009) uses 3.7 fb^{-1} (half of current sample)

Signal decays at 95%CL to be measured

Trigger acceptance ratio from MC approx. 0.2-0.3

Rec. efficiency ratio from MC/DATA approx 0.8

$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = \frac{N_s}{N_+} \cdot \frac{\alpha_+}{\alpha_s} \cdot \frac{\epsilon_+}{\epsilon_s} \cdot \frac{1}{\epsilon_N} \cdot \frac{f_u}{f_s} \cdot \mathcal{B}(B^+),$$ PDG08

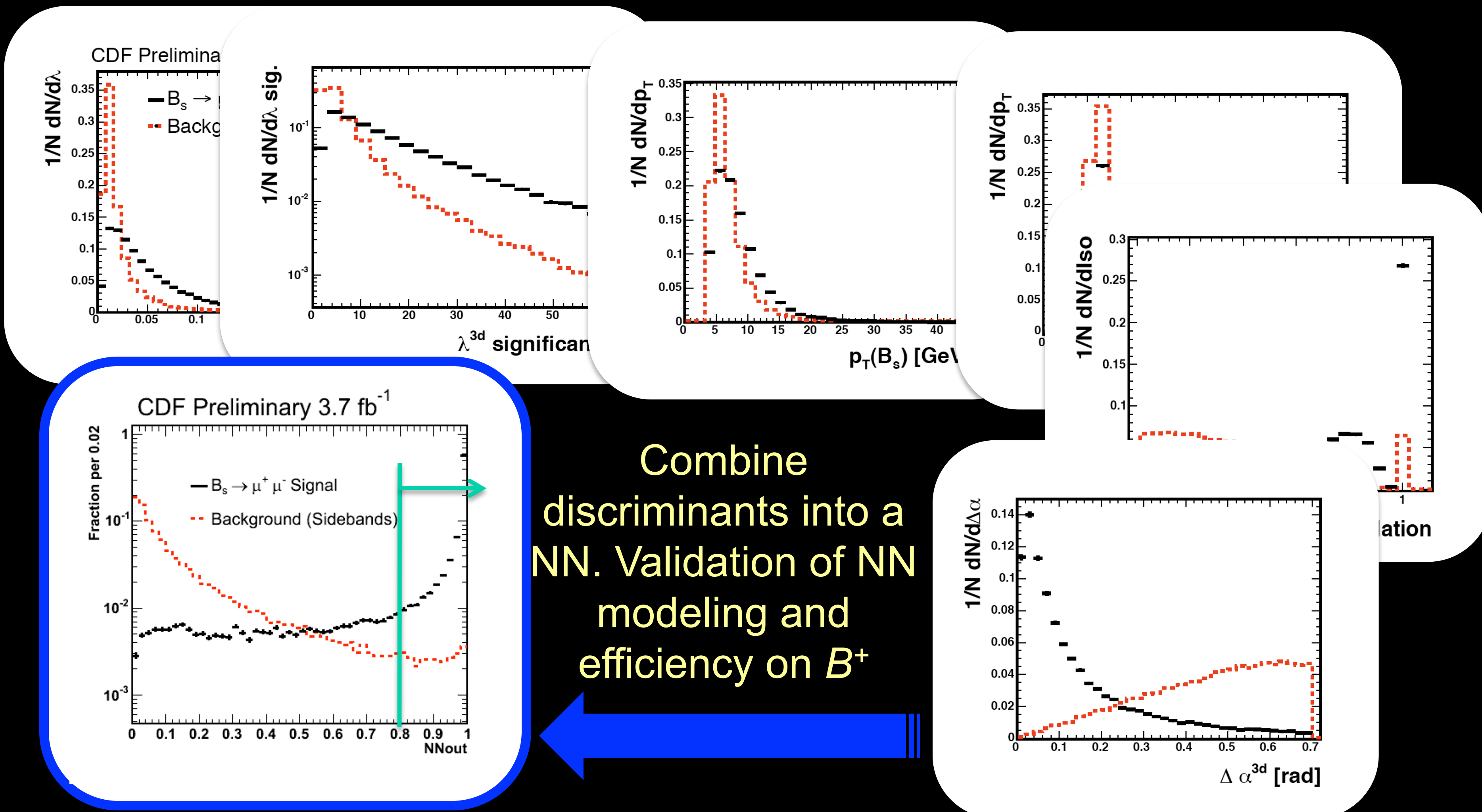
$B^+ \to J/\psi K^+$ decays from data approx. 20K

Efficiency of NN requirement from MC, approx 80-20% (cut-dependent)

The challenge: reject 10^6 background while keeping signal efficiency high.

$B^0_s \to \mu^+\mu^-$ - selection

Discriminants: mass, life, p_T (obvious), B isolation and pointing to $p\bar{p}$ vertex



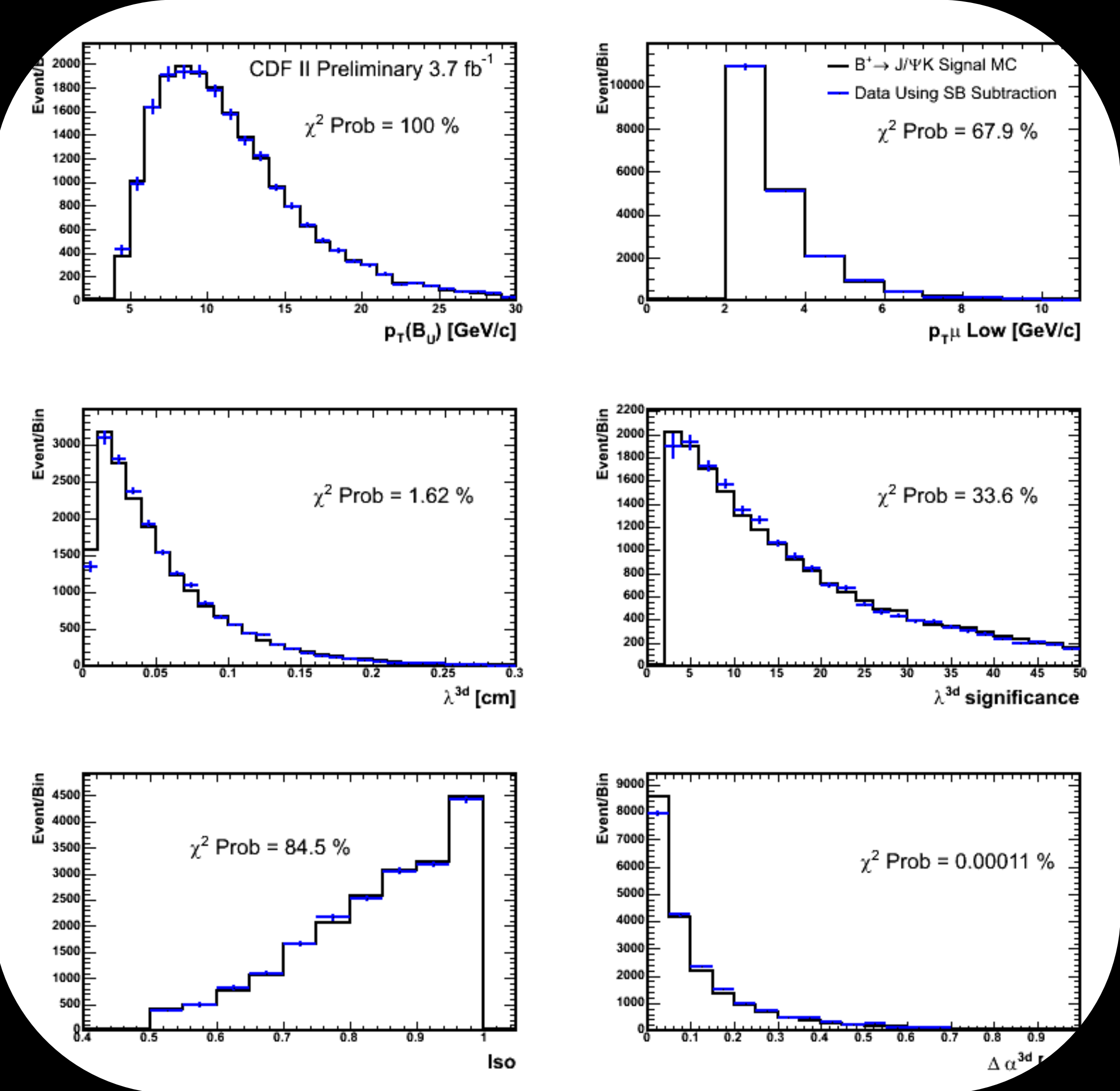
Combine discriminants into a NN. Validation of NN modeling and efficiency on B^+

B→μ⁺μ⁻ – *NN validation*

Detailed MC-data validation using control mode.

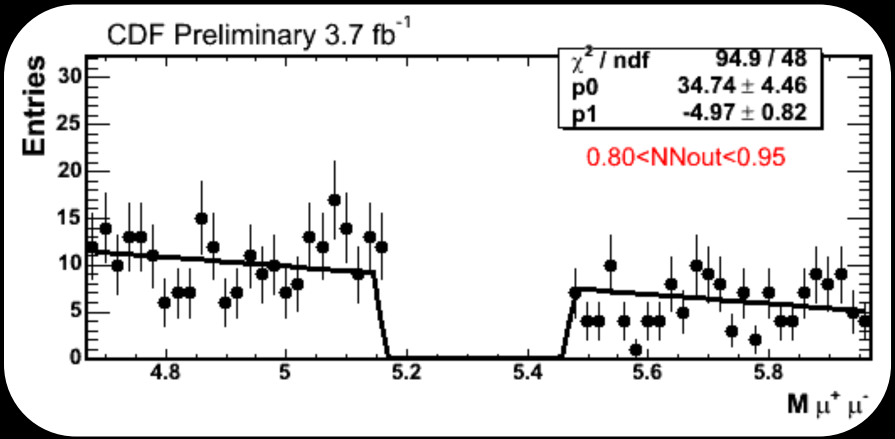
Need for isolation and momentum reweighing.

< 4% residual discrepancies



$B^0_s \to \mu^+\mu^-$ - backgrounds

- ✓ continuum $\mu^+\mu^-$ from Drell-Yan
- ✓ sequential $b \to c\mu^- X \to \mu\mu s$ semilept.
- ✓ double semileptonic $b\bar{b} \to \mu^+\mu^- + X$
- ✓ $b/c \to \mu$ + fake
- ✓ fake + fake (peaking $B \to hh$)



Suppress fakes: calorimeter, dE/dx, muon-track matching.
All calibrated on $J/\psi \to \mu\mu$, $D^0 \to K\pi$, $\Lambda \to ph$ decays in data.

Combinatorial: extrapolate from sidebands into signal region

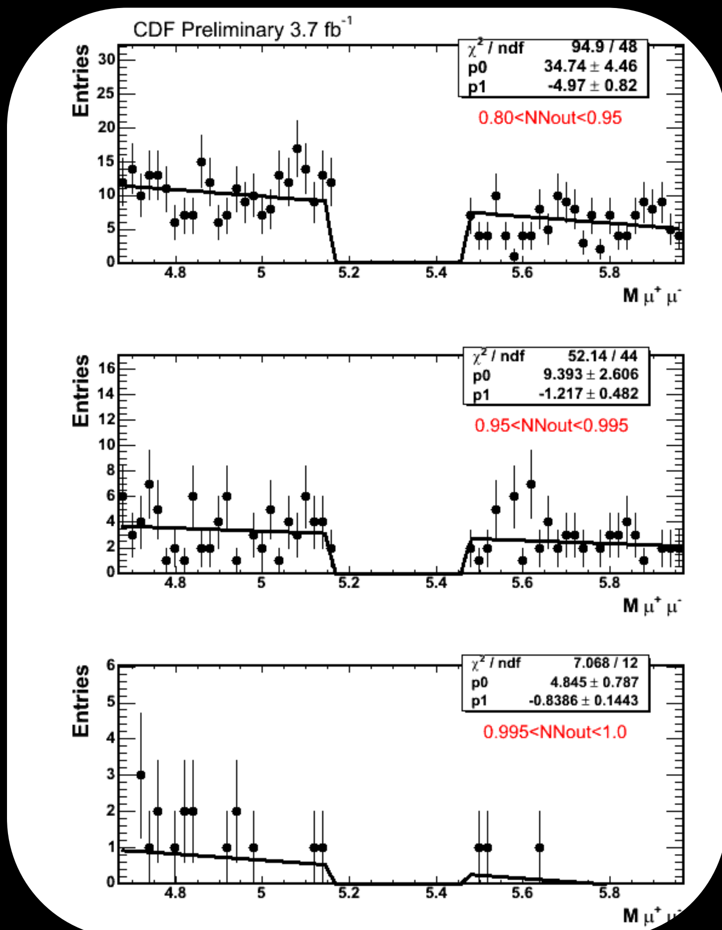
Extensive checks with background-enriched control samples: same-sign dimuons, dimuons with <0 decay-length, dimuons failing fake veto

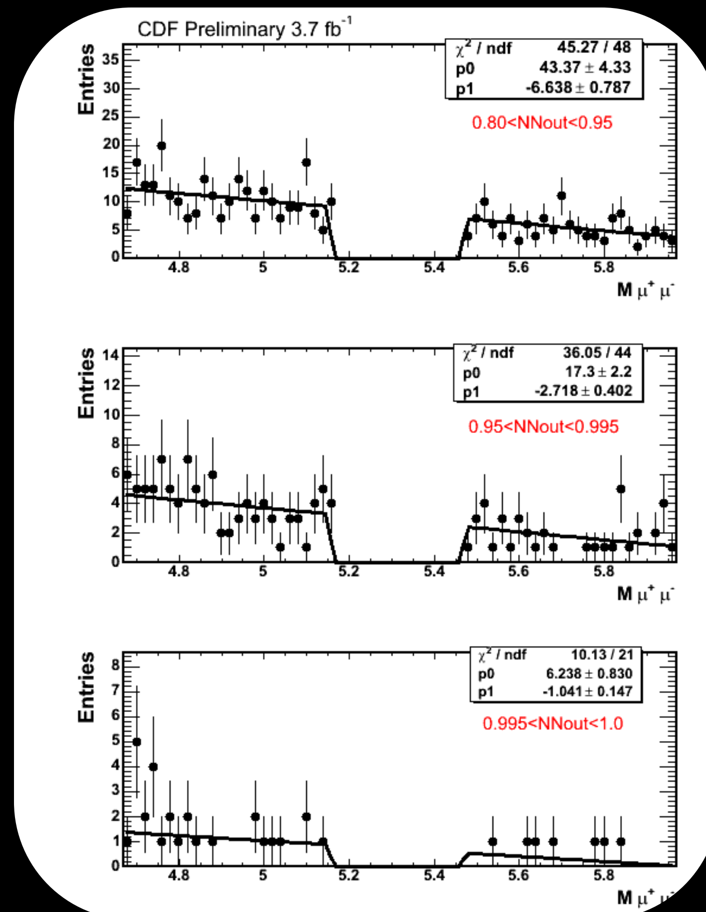
$B \to \mu^+\mu^-$ – *background control*

sample	NN cut	CMU-CMU pred	CMU-CMU obsv	CMU-CMU prob(%)	CMU-CMX pred	CMU-CMX obsv	CMU-CMX prob(%)
OS-	$0.80 < \nu_{NN} < 0.95$	$275 \pm (9)$	287	26	$310 \pm (10)$	304	39
	$0.95 < \nu_{NN} < 0.995$	$122 \pm (6)$	121	46	$124 \pm (6)$	148	3.2
	$0.995 < \nu_{NN} < 1.0$	$44 \pm (4)$	41	36	$31 \pm (3)$	50	0.4
SS+	$0.80 < \nu_{NN} < 0.95$	$2.7 \pm (0.9)$	1	29	$2.7 \pm (0.9)$	0	10
	$0.95 < \nu_{NN} < 0.995$	$1.2 \pm (0.6)$	0	34	$1.2 \pm (0.6)$	1	66
	$0.995 < \nu_{NN} < 1.0$	$0.6 \pm (0.4)$	0	55	$0.0 \pm (0.0)$	0	-
SS-	$0.80 < \nu_{NN} < 0.95$	$8.7 \pm (1.6)$	9	49	$5.7 \pm (1.6)$	2	11
	$0.95 < \nu_{NN} < 0.995$	$3.0 \pm (1.0)$	4	36	$3.6 \pm (1.0)$	2	34
	$0.995 < \nu_{NN} < 1.0$	$0.9 \pm (0.5)$	0	43	$0.3 \pm (0.3)$	0	70
FM+	$0.80 < \nu_{NN} < 0.95$	$169 \pm (7)$	169	50	$73 \pm (5)$	64	19
	$0.95 < \nu_{NN} < 0.995$	$55 \pm (4)$	43	9	$19 \pm (2)$	18	49
	$0.995 < \nu_{NN} < 1.0$	$20 \pm (2)$	20	48	$3.6 \pm (1.0)$	3	53

Predicted vs observed backgrounds in 4 control sample for 3 different NN cuts: 24 independent checks of bckg estimation method.

$B \to \mu^+\mu^-$ – *background control*





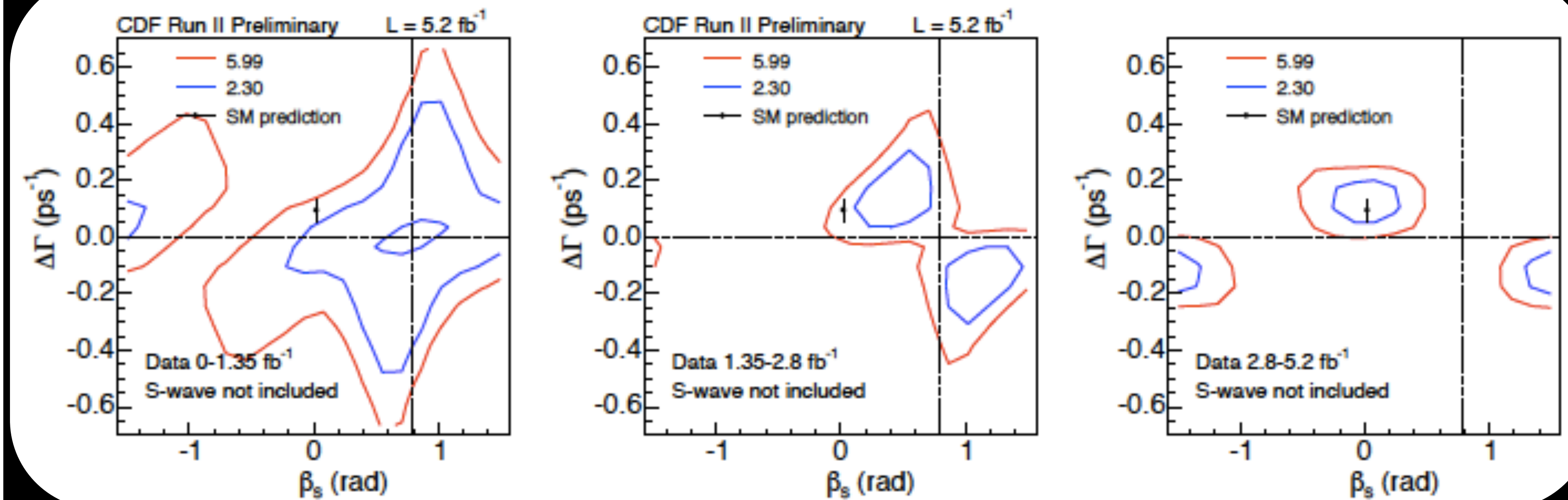
Combinatorics from linear fit to sidebands. Use exp for systematics.

$B \to \mu^+\mu^-$ – *results*

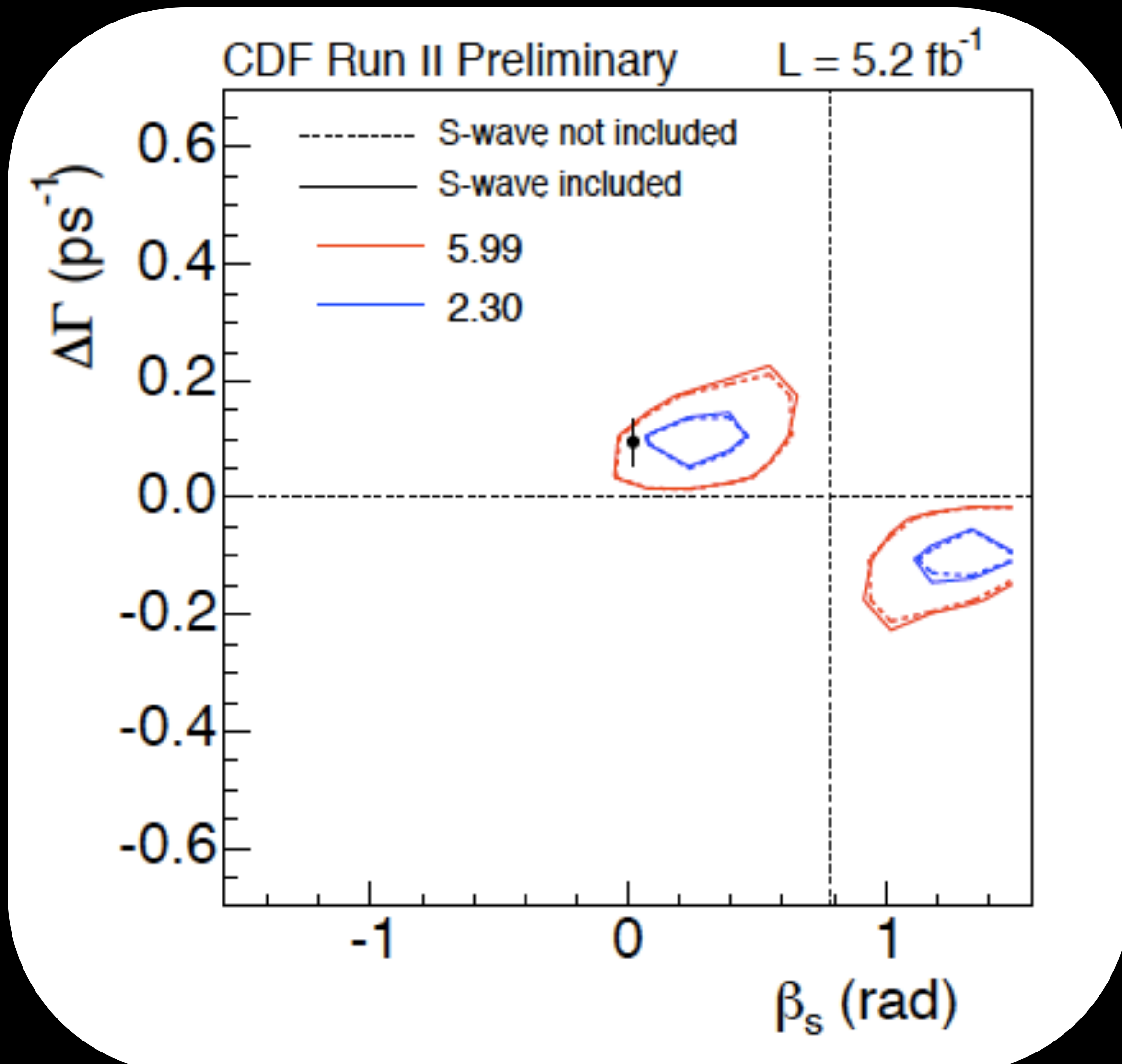
	Mass Bin (GeV)	5.310-5.334	5.334-5.358	5.358-5.382	5.382-5.406	5.406-5.430	Total
UU NN bin 0.80-0.95	Exp Bkg	9.66 ± 0.47	9.46 ± 0.46	9.27 ± 0.46	9.08 ± 0.46	8.88 ± 0.45	46.3 ± 2.4
	Obs	7	5	10	5	5	32
UU NN bin 0.95-0.995	Exp Bkg	3.42 ± 0.27	3.33 ± 0.27	3.25 ± 0.27	3.17 ± 0.26	3.09 ± 0.26	16.2 ± 1.4
	Obs	2	3	4	3	5	17
UU NN bin 0.995-1.0	Exp Bkg	0.869 ± 0.17	0.821 ± 0.18	0.783 ± 0.19	0.75 ± 0.19	0.717 ± 0.21	4.0 ± 1.0
	Obs	0	1	2	0	0	3
UX NN bin 0.80-0.95	Exp Bkg	9.94 ± 0.48	9.8 ± 0.48	9.66 ± 0.48	9.51 ± 0.47	9.37 ± 0.47	48.3 ± 2.4
	Obs	12	8	9	9	5	43
UX NN bin 0.95-0.995	Exp Bkg	3.5 ± 0.29	3.47 ± 0.29	3.43 ± 0.29	3.39 ± 0.29	3.36 ± 0.29	17.2 ± 1.4
	Obs	3	4	3	7	0	17
UX NN bin 0.995-1.0	Exp Bkg	0.467 ± 0.14	0.438 ± 0.15	0.412 ± 0.15	0.387 ± 0.16	0.362 ± 0.16	2.08 ± 0.78
	Obs	1	1	0	1	1	4

Table 10: B_s signal window for CMU-CMU(top) and CMU-CMX(bottom): Expected backgrounds, including $B \to hh$, and number of observed events

Checks


CDF Run II Preliminary
L = 5.2 fb^{-1}
5.99
2.30
SM prediction
$\Delta\Gamma$ (ps^{-1})
β_s (rad)
Data 0-1.35 fb^{-1}
S-wave not included
Data 1.35-2.8 fb^{-1}
S-wave not included
Data 2.8-5.2 fb^{-1}
S-wave not included

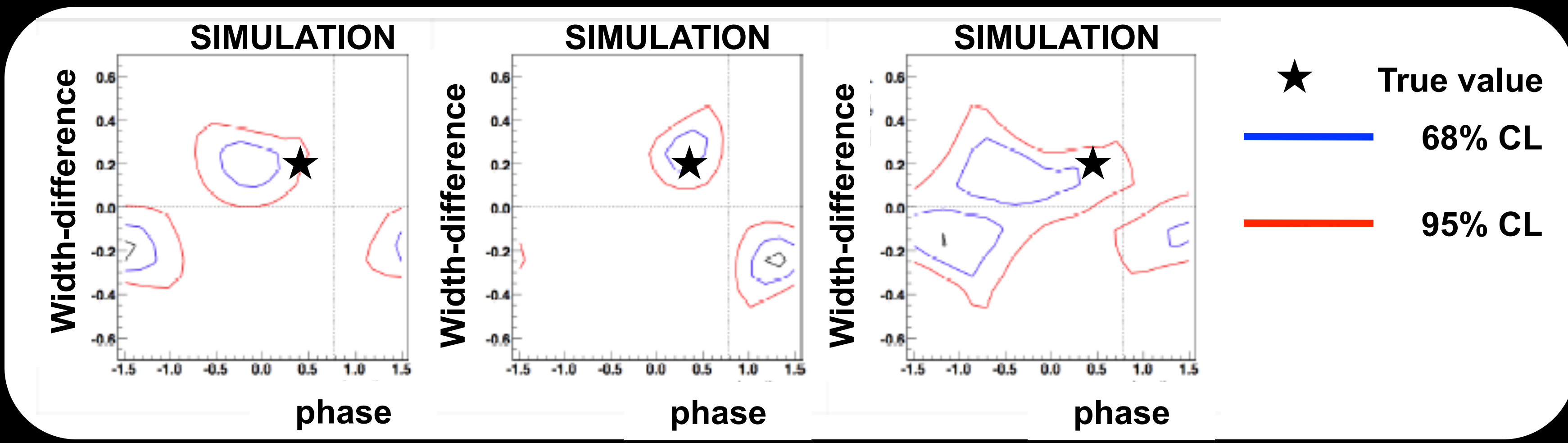
Checks



CDF Run II Preliminary
L = 5.2 fb-1
S-wave not included
S-wave included
5.99
2.30
ΔΓ (ps-1)
βs (rad)
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-1
0
1

Mixing phase - *Likelihood features*

1σ and 2σ Likelihood contours in the ($\Delta\Gamma$, βs) plane.

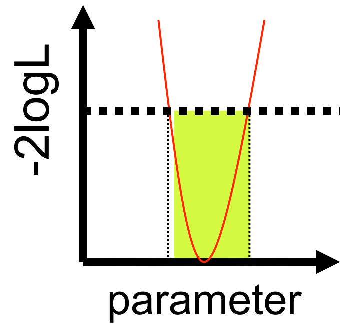


Wild fluctuations. Likelihood has two minima – strongly non-Gaussian

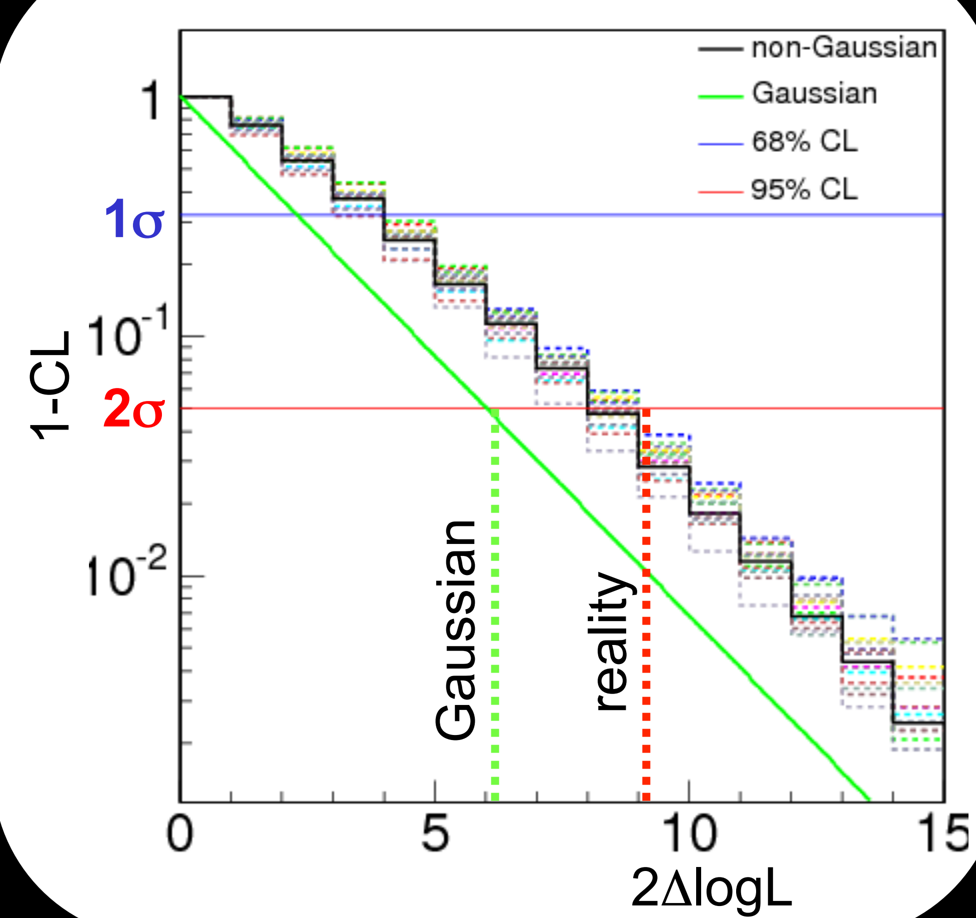
Not reporting central values and their uncertainties. Use interval estimation (confidence regions) instead.

Mixing phase - *Enforcing coverage*

Standard likelihood ratio method fails



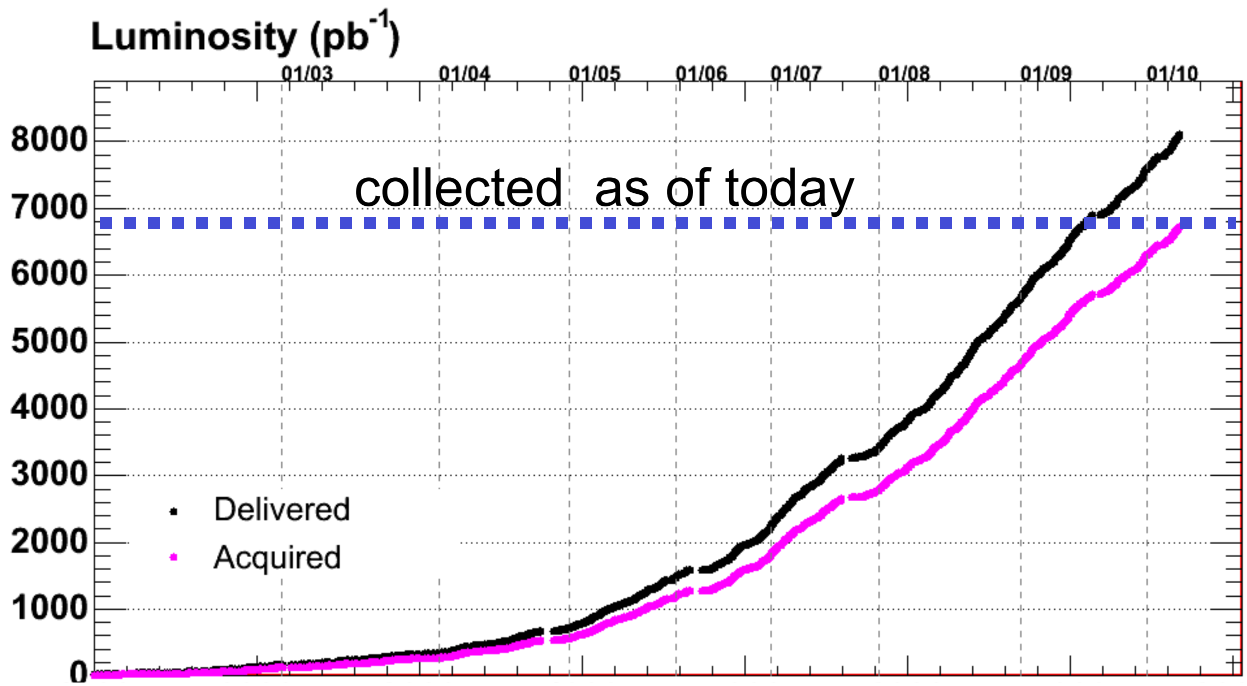
Remap observed 2ΔlogL distribution in terms of actual CL from toys. E.g. to get the 95.5% CL, 2ΔlogL~9 units (as opposed to 5.99 asymptotic)



Include systematics: vary nuisance parameters within 5σ of their estimates on data. Use worst case.

arXiv:0810.3229

What next?



More than 10 fb^{-1} of physics-quality data on tape by end of 2011